Naval Architecture and Ocean Engineering Department

Professor Bruce C. Nehrling
Chair

The faculty and midshipmen associated with the two engineering disciplines taught by the Naval Architecture and Ocean Engineering Department actively pursued scholarly research and professional development during Academic Year 2002. These efforts were enhanced by having a post-doctoral researcher temporarily join the department. As this diverse group undertook both funded and unfunded research activities, significant use was made of the Naval Academy's outstanding experimental, computational, and library facilities. The broad spectrum of research themes addressed reflects the varied specialties' resident within the department's areas of technical concentration.

Naval Architecture topics included studying and testing the effect of tensile and compressive loads on composite masts, specifying potential hull laminates for the new Navy 44 vessel, developing a finite element analysis for a composite hull, re-evaluating the ABS Wooden Vessel Rules in light of new fabrication techniques, and advising on the design and fabrication of a trimaran for the Solar Splash competition. Experiments in the Hydromechanics Laboratory involved predicting the slow speed seakeeping behavior of an unconventional hydrofoil hull, measuring surface and near-surface submarine suction forces, evaluating rudder designs for the new Navy 44, and acquiring and correlating performance data for the U.S. Coast Guard's 47' motor lifeboat.

Ocean engineering topics included experiments into the random behavior of wave groups, the performance of submarines while transiting navigational channels, wave forces generated by passing ships on moored vessels and piers, the hydrodynamic characteristics of painted lifting surfaces, the performance of a port security barrier, phenomena associated with the detachment of low form fouling, and the performance of fouling-release surfaces. In materials and structures, research began on how to best provide noise damping in composites and continued in the analysis of adhesively bonded composite joints. Other projects investigated the performance of a passively controlled rebreather, the design and use of catalytic heaters for the thermal protection of divers, methods for the control of excess oxygen in submarine rescue vehicles, the hydrodynamic behavior of artificial reefs, the environmental impact of various surface mining reclamation methods, and the use of computer models to measure shore line erosion patterns. Finally, a multi-year study was completed on the technical, operational, and economic issues affecting the design and maintenance of navigable channels.

Research funding was made available from many sources including department operating funds and contracts and grants from the Office of Naval Research (ONR), the Naval Facilities Engineering Services Center, the U.S. Army Corps of Engineers Waterways Experimental Station, the Institute for Water Resources, the Naval Sea Systems Command (NAVSEA), the National Science Foundation (NSF), the Naval Surface Warfare Center - Carderock Division (NSWC-CD), the Maritime Applied Physics Corporation, Team Dennis Conner, and the 3M Corporation. The faculty, staff, and midshipmen of this department appreciate the cooperation and support provided by these sponsoring agencies and organizations.

The department's faculty, staff, and midshipmen continue to participate actively in professional meetings and conferences - both nationally and internationally. Thirteen manuscripts were published or accepted in professional journals, twenty-three articles appeared in conference proceedings, three patent applications or awards were made, and numerous technical reports were written. In addition, approximately forty presentations were made at a wide-range of national and international symposia. An energized and up-to-date academic environment for both core and major courses is one beneficial outcome of this department's extensive and significant involvement in research.

Sponsored Research

Wave Groups and Wave Breaking in Random Seas

Researcher: Professor Thomas H. Dawson
Sponsor: Office of Naval Research (ONR)

Wave groups in random deep-water waves are being studied experimentally using the Naval Academy's 380-foot wave/towing tank. Results to date have been compared with theoretical work that accounts for nonlinear effects on crest amplitudes. Recent work has been concerned with investigation of wave-group statistics derived from Markov theory for wave runs and with the effects of breaking waves on group statistics.

Investigation of Submarine Performance in Restricted Waterways

Researcher: Associate Professor Jennifer K. Waters
Sponsor: Naval Surface Warfare Center - Carderock Division (NSWC-CD)

Navigation channels are typically designed for the transit of primarily surface vessels. However, the safe and efficient transit of submarines through our waterways is essential to our national defense. This study calibrated and validated a numerical hydrodynamic computer model with existing physical experimental model test data. The numerical model is being used to predict submarine motions and performance during navigation channel transits.

Investigation of Passing Ship Effects on Moored Vessels Alongside Deep Draft Waterways

Researcher: Associate Professor Jennifer K. Waters
Sponsor: U.S. Army Corps of Engineers, Waterways Experiment Station

This research work is an extension of previous work performed for the U.S. Army Corps of Engineers on Deep-Draft Navigation Channel Design. The new work investigated the impact of moving vessels on other stationary vessels moored alongside a navigation channel. There have been several recorded instances of ships breaking mooring lines due to the forces created by a passing ship. This study attempted to investigate, quantify and develop an approach for controlling or managing these forces through navigation channel design and/or waterway management.

Investigation and Integration of Technical, Operational and Economic Issues Affecting Navigation Channel Design and Maintenance

Researchers: Associate Professor Jennifer K. Waters,
Associate Professor Robert H. Mayer, and Professor David L. Kriebel
Sponsor: Institute for Water Resources, U.S. Army Corps of Engineers (IWR-USACE)

The goal of the Institute for Water Resources (IWR) work unit #33123: "Impacts of Navigation Trends on Channel Usage and Design" is to improve the design and maintenance of navigation channels in order to achieve economic efficiency, reliability, and safety of shipping operations. Specifically, this study investigated how changes occurring in the international shipping industry may impact the way the U.S. Army Corps of Engineers (USACE) designs and maintains its channels. The study was also concerned with how navigation trends on channel usage may contribute to safety, piloting, and maintenance problems.

A critical element in the work unit is an updated review of both domestic and international practices for the design and maintenance of navigation channels. Another critical element of the work unit is an investigation into how channels are actually being maintained and utilized, *after* the design process has been completed. This part of the study incorporated an analysis of channel accident data with specifics of vessel navigation and dredging operations. This is important since it is well recognized that navigation channels are not necessarily maintained or utilized as they were originally designed.

The goal of this work effort was to support IWR's work unit #33123 through completion of related tasks. Specifically, the researchers were involved in identifying, investigating and integrating many of the technical, operational, and economic issues affecting navigation channel usage, design and maintenance. Recommendations to mitigate any problematic issues in USACE policy, guidance, or practice are forthcoming.

BESTEAMS Model of Team Development Across the Curriculum

Researcher: Associate Professor Sarah E. Mouring
Sponsor: National Science Foundation (NSF)

The Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS) Partnership is involved in engineering project team training research and includes faculty from the University of Maryland, Morgan State University, Howard University, and the U.S. Naval Academy. This partnership is developing a four-year, team training curriculum model that can be integrated into any existing engineering curriculum. Full development of the model will include preparation of a complete undergraduate curriculum on team development topics, supportive faculty training workshops, and materials for formative and summative evaluation and research. The curriculum and supportive materials will be disseminated nationally via conferences, workshops, the BESTEAMS website and a national publication. Much of the early research includes development of the team training curriculum at the Partnership institutions.

Behavior of Composite Joints Adhesively Bonded Using An Innovative Joining Method

Researcher: Associate Professor Sarah E. Mouring
Sponsor: National Science Foundation (NSF)

The research involves the development of a new bonding method to join composite structural elements. The proposed method is a combination of liquid adhesive/adhesive tape technology, involving the use of adhesive tape to temporarily secure and create a channel between structural parts to be joined. The liquid adhesive then is pumped into the channel to form a permanent bond. This allows multi-part structures to be "tacked" together quickly, checked for accuracy, and then permanently bonded later by injecting the adhesive. As part of the development and evaluation of the proposed joining method, analytical procedures are being developed to model several different joint configurations. These models are being used to optimize joint designs. Experimental tests are being performed to validate the analytical models. In the final year of the grant, analytical and experimental research will be performed on the current joining method used in Civil Engineering, and compared to the results of the proposed method. Also, guidelines on testing joints bonded using the new method will be suggested. At this time, six technical papers on the results of the research have been published.

Ship Generated Waves

Researcher: Professor David L. Kriebel
Sponsor: Naval Facilities Engineering Services Center

Waves generated by passing commercial ships often create problems in Navy ports. For example, these waves can excite large dynamic motions of moored Naval vessels and, as a result of the large forces transmitted in the mooring lines, either the moored ship or the pier can experience damage. Because of these damages, the Naval Facilities Engineering Command has initiated an investigation of the ship-generated waves with the goal of developing engineering design guidance for predicting the characteristics of these waves as a function of ship hull geometry, ship speed, water depth, and the distance from the passing ship sailing line. While ship-generated waves in deep water are understood fairly well, ship-generated waves in shallow water are not well understood. As a result, model tests are underway in the Naval Academy Hydromechanics Laboratory in shallow water conditions where the ship draft is 50 to 90 percent of the water depth.

Composite Materials Research for Team Dennis Conner

Researcher: Assistant Professor Paul H. Miller
Sponsor: Team Dennis Conner

This project included research, analysis, testing and design of composite material components for two 78-foot racing vessels to be used in the 2003 America's Cup competition.

Specific tasks included:

a) Finite element analysis (research and development) of proposed hull, deck, rig and internal structure configurations. FEA models of the hull and rigs were created to assist in the design of the final parts.

b) Tensile and compressive testing of approximately 50 coupons on the Naval Academy's SATEC machine.

c) Testing of composite mast pieces. Two pieces were tested for compression strength after impact and two for critical wall-buckling loads. Testing of deck component.

d) Specification of laminates of composite components including hull, deck, internals, mast and rudder.

Passively Controlled Semi-Closed/Closed Rebreather Development

Researcher: Professor Marshall L. Nuckols
Sponsor: Office of Naval Research (ONR)

This is the third year of a 3-year research effort to develop a versatile, passively-controlled semi-closed rebreather for deep diving applications that can be switched to closed-circuit mode during shallow water missions (depths less than 25 feet). Such a design is desired to safely satisfy the full range of Naval Special Warfare missions without the complexity and cost of electronically-controlled closed circuit rebreathers. The objectives of this effort are to optimize the design of respiratory-coupled circuit designs (using variable volume exhaust injection systems) using analytical predictive models, and verify from unmanned testing that safe alternatives to traditional semi-closed circuit designs are feasible. In so doing, we will demonstrate that respiratory-coupled rebreather designs will provide divers with stable, and predictable circuit oxygen levels across their full range of activity levels.

Hydrogen Catalytic Heater for SDV Applications

Researcher: Professor Marshall L. Nuckols
Sponsor: Office of Naval Research (ONR)

This is the third year of a 3-year effort to develop a safe and efficient diver heater to minimize package size and power requirements and yet meet the entire diver heating requirements for long duration Naval Special Warfare (NSW) missions. The technical objectives of this effort are to a) conduct a tradeoff analysis of different active heating methods for swimmer delivery vehicle (SDV) applications to quantify and compare the energy densities of each approach, b) construct a prototype heating circuit containing a heat exchanger incorporating a palladium on carbon catalyst bed, and c) conduct laboratory testing of prototype hydrogen catalytic heater and water heat exchanger to verify the energy density available from this heating method.

Development of An Oxygen "Metabolizer" To Control Oxygen Levels in the Closed Cabin Of Rescue Vehicles

Researcher: Professor Marshall L. Nuckols
Sponsor: Naval Sea Systems Command (NAVSEA)

This is the first year of a 2-year effort to develop an oxygen "metabolizer" using a hydrogen catalytic reactor to consume excess oxygen within the closed cabin atmosphere of a submarine rescue vehicle. Such a catalytic reactor has been shown to give an effective method of reducing the level of oxygen in diver breath heating and diver whole-body heating systems. It is expected that the experience gained from this unmanned testing application will greatly simplify unmanned

testing of closed and semi-closed breathing apparatuses, and that this metabolic oxygen consumption technology will be directly applicable to later applications with human vehicles.

The Relationship Between the Detachment of Low Form Fouling at Lab and Ship Scale

Researcher: Assistant Professor Michael P. Schultz
Sponsor: Office of Naval Research (ONR)

The introduction of non-toxic, fouling-release coating systems as alternatives to traditional biocide based antifoulings has necessitated a change in coating evaluation protocol. Since fouling-release systems do not prevent settlement, various methods to quantify the tenacity of adhesion of fouling organisms on these systems have been offered. Data from these tests are of particular importance because fouling-release surfaces that cannot "self clean" due to hydrodynamic forces or be mechanically cleaned without significant damage will likely suffer large drag penalties. The question remains, however, how the results from these laboratory scale tests relate to the self-cleaning of a ship coated with a fouling-release surface. The goal of the research is to better relate the detachment strength of low form fouling determined by the turbulent channel flow apparatus to the conditions necessary for detachment of these organisms in a turbulent boundary layer at ship scale.

Comparison of the Hydrodynamic Performance of Fouling-Release Surfaces with Copper-Based Antifouling Coatings

Researcher: Assistant Professor Michael P. Schultz
Sponsor: Office of Naval Research (ONR)

The primary purpose of a ship antifouling system is to limit the increase in drag that will be incurred with fouling settlement on the hull. Ineffectiveness in this endeavor will lead to an increase in energy consumption and a platform that is unable to meet its mission. The introduction of non-toxic, fouling-release coating systems as alternatives to traditional biocide-based antifoulings has necessitated a change in philosophy with respect to these coatings. Since fouling-release coatings do not prevent settlement, various methods to quantify the tenacity of adhesion of organisms on these systems have been offered. Among these are the hard fouling adhesion test, the water jet cleaning method, the towed foil technique, and the turbulent channel flow apparatus. Data from these tests are of particular interest because fouling-release surfaces that cannot "self clean" due to hydrodynamic forces or be mechanically cleaned without significant damage will likely suffer large drag penalties. For these systems to serve as viable alternatives to traditional biocide-based systems, their hydrodynamic performance must compare favorably with traditional systems over the entire coating life cycle. At present, the data from which to make these fundamental comparisons are not available. The goal of the present research is to compare the hydrodynamic performance of the fouling-release coating systems and traditional copper-based systems in the unfouled, fouled, and cleaned conditions over several cleaning cycles and several years exposure.

Slow-Speed and Zero-Speed Seakeeping Model Tests of the 2200 LT MCM(XH) HYSWAS Hull Form

Researchers: Professor Gregory J. White
and Mrs. Nancy A. Harris, Naval Architect (Hydro Lab)
Sponsors: Maritime Applied Physics Corporation and the Office of Naval Research (ONR)

A tank model test series has been performed for the specific purpose of measuring the low-speed seakeeping performance of the hull form. The model was configured with foils to provide an accurate representation of the added-mass effects of these surfaces. The model was ballasted to reflect two different loading conditions, a light condition (2,000 LT) and a full load condition (2,200 LT). Measurements were recorded for pitch angle, pitch rate, roll angle, roll rate, heave acceleration, wave height, and forces at the top and bottom of the hull strut. Using this information, the roll and pitch accelerations and the bending moments on the strut were also determined. Tests were conducted for zero-speed and slow-speed (3 knots full scale) in sea state conditions 3, 4, 5, and 6. During the zero-speed tests, runs were conducted with relative headings (to the waves) of 0, 30, 60, 90, 120, 150, and 180 degrees. All of the towed tests were conducted in head seas only, with the addition of a sea state 8 test run.

The HYSWAS model performed much as was expected during both test series. The zero-speed pitching motions were worse as the vessel approached head or following seas. The zero-speed rolling motions worsened as the heading approached beam seas. There was some generally small reductions in the rolling and pitching motion at the heavier displacement in the zero-speed tests. The bending moments determine from the force measurements were quit large and dramatically increased as the relative heading approached 90°.

Independent Research

Redesign of Navy 44 Hull Laminate

Researcher: ENS Mark Arvidson, USNR
Adviser: Assistant Professor Paul H. Miller

During his post-graduation three-week long temporary duty assignment with the Naval Architecture and Ocean Engineering Department, ENS Arvidson completed the preliminary structural design of the new Navy 44 vessel. This work included specifying all of the laminates known to be included in the new design, creating the materials list and generating the structural drawings. In addition, each laminate was checked against the appropriate ABS and IMS rules.

Evaluation of Composite Hull and Deck with FEA

Researcher: Midshipman 1/C Matthew Davin, USN
Adviser: Assistant Professor Paul H. Miller

During a summer internship, the researcher participated in the design of an America's Cup yacht for the 2003 competition. Midshipman Davin began his internship with a trip to San Diego to spend the weekend sailing an example of this type of boat. He then proceeded to Los Angeles for a three-day course in finite element analysis. Upon his return to the Naval Academy, he practiced with the finite element program and was given the task of improving the vessel's stiffness while reducing weight. Mr. Davin developed a number of potential solutions and presented them to the design team. He then performed a detailed design of the solution that was finally incorporated into the vessel's design.

Bioengineering Study of the Cardiovascular System of Mammals

Researcher: Professor Thomas H. Dawson

The cardiovascular system of mammals is studied using engineering principles and their application to the design and process of the system. A consequence of this work has been the discovery of the scaling laws governing the cardiovascular system of mammals, including humans. Publications include the earlier book: Engineering Design of the Cardiovascular System of Mammals (Prentice Hall Bioengineering Series) and the more recent paper: "Similitude in the Cardiovascular System of Mammals" (Journal of Experimental Biology, Vol. 204, pp.395-407, February 2001). Work is continuing as time and circumstances permit.

Research Course Projects

A Hydrodynamic Study of Artificial Reefs

Researcher: Midshipman 1/C Tara Inverso, USN
Adviser: Associate Professor Jennifer K. Waters

The research detailed in this report centers around a new and unique form of artificial reefs called Reef Balls. These semi-spherical pieces are used in conjunction with each other to form artificial reefs on the seafloor. Though they are used in over 400 projects worldwide, they have not been the focus of scientific study and research.

In this study, tests were performed in the U.S. Naval Academy Hydromechanics Laboratory's Coastal Basin and 120' tank. The coastal basin tests concluded that artificial reefs constructed of reef balls reduce wave energy by a range of four to nineteen percent, depending on the depth of the reef and frequency of the waves. Tests in the 120' tank concluded that reef balls have a coefficient of drag ranging from 0.35 to 0.69, depending on the orientation of the holes.

The Environmental Impact of Surface Mining: Using Land Reclamation Techniques as a Remedy

Researchers: Midshipman 1/C Trevor J. Felter, USN and Midshipman 1/C Andrew M. McKee, USN
Advisers: LT Gwen D. Clifford, USN and Associate Professor Jennifer K. Waters

Land reclamation is the process where land that has been mined is recovered and returned to a state of productivity. This is accomplished by moving massive amounts of earth, rerouting water, and even decontaminating groundwater and watershed areas. Land reclamation must be started before mining can even occur according to the Surface Mining Control and Reclamation Act of 1977.

The objective of this research project was to determine the problems associated with surface mining and land reclamation through the use of bio-solids. Acid drainage, groundwater and watershed contamination, infertility, and the erosion of topsoil are all environmental problems associated with surface mining. Wyoming and Pennsylvania export 69.4 million and 5 million short tons of coal a year, respectively. Practical knowledge of the aforementioned problems were obtained from personally traveling to Pennsylvania Department of Environmental Protection (Ebensburg District Office) through performance of on-site studies as well as interviews obtained from experts within the industry. The research project examined the processes of land reclamation from the beginning of an issuance of a bond to the crop production of revitalized surface mines.

Seakeeping of Advanced Marine Vehicles

Researcher: Midshipman 1/C John Campbell, USN
Adviser: Professor Rameswar Bhattacharyya

This project was divided into two distinct parts and had several goals. The two separate sections were a seakeeping study of advanced marine vehicles and an experiment with a Series 58 body to test submerged suctions forces. The goals of the seakeeping study were to research technical publications and experiments in order to provide a general description of the seakeeping characteristics of each type of vessel and to develop a better understanding of seakeeping evaluation in general. The goals of the experimental test were to gain familiarity with tank testing procedures and develop some raw data for analysis and comparison with published data and theory.

The tow tank test used a five-foot Series 58 model with a diameter of 8.9 inches and submerged volume of 1.33 cubic feet. The initial phases of the experiment were dedicated to determining the test matrix and setting up the model. The 120' tank was to be used in order to allow single-handed operation of the carriage and data acquisition equipment. In order to simulate a wide variety of waves and remain within the limits of the wavemaking apparatus, a five-frequency range was chosen. These frequencies varied from 0.4 to 1.2 Hertz and 0.2 Hz intervals. In order to simplify data collection and analysis, wave slope and carriage velocity were held constant at $1/60^{th}$ slope and four feet per second, respectively. The model was tested at two depths, four and eight inches, which equate to one-half and one diameter.

Port Security Barrier Model Testing

Researcher: Midshipman 1/C James Henry, USN
Adviser: Professor David L. Kriebel
Sponsor: Naval Facilities Engineering Services Center (NFESC)

Two proposed designs for floating security barriers were tested in the wave tanks of the Hydromechanics Laboratory. The first barrier type, the Port Security Barrier (PSB), was tested to evaluate: (a) its resistance to towing and (b) its response in waves. In the first set of tests, a single module of the barrier was towed in the 120' wave tank at various angles of attack while

forces on the hull were measured. In the second set of tests, several modules were joined together to span the 380' wave tank and were subjected to various wave conditions. The structure motions were recorded along with the tension in the connectors between modules. The second barrier type, the Near Port Security Barrier (N_PSB), was tested to evaluate its motions in waves when placed against a ship hull. This type of barrier has rollers to ride up-and-down the hull as it moves in waves. Tests were conducted to record its dynamic motions in heave and roll. Results of this project were used by NAVFAC during the final design phase of the PSB and N-PSB, and full-scale units were installed at several Naval bases in the winter of 2001-2002 following testing.

GIS Analysis of the Severn River Shoreline Using MICRODEM

Researcher: Midshipman 1/C Roy Dalton, III, USN
Advisers: Professor David L. Kriebel
and Professor Peter L. Guth (Oceanography Department)

This project used a Geographical Information System (GIS) software package called MICRODEM, written by Professor Peter Guth at the U. S. Naval Academy, to analyze shore erosion and shore protection methods on a portion of the Severn River shoreline. The goal of the project was to integrate map data obtained from the Maryland Department of Natural Resources (MDNR) with field data gathered during the project to provide a single interface for analysis of all data pertinent to shoreline management. At present, the Maryland Department of Natural Resources does not have a single database or mapping tool that can be used to identify erosion trends, shoreline types, and the existence of erosion control structures on a property-by-property basis.

This project produced a single-source GIS map and database to help MDNR manage the Severn River shoreline. This GIS system includes four basic components. First, a digital aerial photograph from 1994 (latest available) is used to visually display the area of interest. Second, historic shoreline maps are superimposed on the aerial photo to illustrate changes in shoreline position due to erosion or accretion. In this project, historic shorelines from 1847, 1934, 1965, and 1994 were used. Third, individual properties were mapped using the MD Property View database provided by MDNR. This data was in the form of a database file that allowed identification of each property along the Severn River. Fourth, the researcher conducted a field survey to take digital photographs of each property and to identify shoreline types. For each property, the percentage of the shoreline was defined in one of several categories: sand beach, clay bluff, vegetated, timber bulkhead, stone revetment, detached breakwater, or concrete bulkhead. The final software package allows all of the above to be mapped and allows the user to simultaneously open the database showing shoreline type and the photograph of the property. The MDNR has plans to conduct similar mapping efforts state-wide based, in part, on the capabilities demonstrated in this project.

New Navy 44 Rudder Research and Design

Researcher: Midshipman 1/C William Huebner, USN
Adviser: Assistant Professor Paul H. Miller

The existing Navy 44 vessels are due for replacement and one area to be investigated for possible improvements is the rudder design. Design criteria for the rudder includes reliability, damage tolerance, drag reduction, leeway resistance and yaw moment generation. Design characteristics are a function of planform, thickness, sweep angle, configuration, section, and aspect ratio. Four basic rudder designs, corresponding to elliptical or trapezoidal planform and skeg or spade configuration were tested on tank models representing the existing 44 design and the midshipman design from 2001. Resistance, side force, and yaw moment were measured as a function of leeway, roll angle and rudder angle. From over 200 runs in the 120-foot tank, the results indicated the elliptical spade produced the most desirable characteristics at small angles of attack, representing a straight line course. At large angles of attack, representing maneuvering situations, the elliptical spade rudder proved superior. Baseline data using the tank test model was compared to full-scale tests with good correlation.

Evaluation of ABS Wooden Vessel Criteria

Researcher: Midshipman 1/C Kent Simodynes, USN
Adviser: Assistant Professor Paul H. Miller

Modern wood construction criteria for boat building have remained unaddressed by American Bureau of Shipping (ABS) for the past twenty years. The drawback this presents to wooden boat construction is that the rules governing ship construction have not paralleled the advancements made in boat building techniques or the materials now available for use in boat hulls. An examination of new fabrication techniques was made and compared through testing and analysis against the ABS Rules. Flexural test coupons representing carvel, strip, sheathed and cold-molded construction using mahogany, cedar, pine and oak were fabricated in the U.S. Naval Academy's Model Shop. The coupons were tested in the Academy's SATEC machine and the results were compared to predictions made by the ABS Rules and classical lamination theory (CLT). The ABS Rules provided close correlation (9%) to the carvel planking results, but underestimated the strength up to 45% for the other construction methods. The maximum CLT error was 16%.

Measurement of Constrained-Layer Damping

Researcher: Midshipman 1/C William D.H. Smith, USN
Advisers: Associate Professor Sarah E. Mouring
and Assistant Professor John A. Burkhardt (Mechanical Engineering Department)
Sponsor: 3M Corporation

Excessive noise is a common problem in the marine industry. There are many methods used for noise control. One such method is the application of constrained-layer damping to the structure. It is important that the correct amount of damping is applied. Too little and the noise is not significantly reduced, and too much and the system is overdamped. Therefore, it is important to optimize the amount of constrained-layer damping in a given system. In order to help in the optimization, a simple experimental test is needed to measure the damping level in a system with constrained-layer damping. The development of one such test was the focus of this research project. Experimental results were compared to theoretical results in order to evaluate the proposed method.

Design of a Solar-Powered Trimaran – Solar Splash Competition 2002

Researcher: Midshipman 1/C Travis Chapman, USN
Adviser: Professor Gregory J. White

Solar Splash is the World Championship of Solar/Electric boating. It is an international competition that takes place each year to allow design teams to compete in five categories for the best design. The U.S. Naval Academy Mechanical Engineering Department decided to use the design competition as the central subject of their senior capstone design course for two groups of First Class Midshipmen. Midshipman Chapman, a Naval Architecture major, completed an independent research project by designing and building a boat for the Naval Academy team.

The trimaran hull-form was chosen due to the limited time for the design and the flexibility in loading and outfitting that it provided. The hull was constructed using a "tortured plywood" method to allow for rapid construction and light weight. The hull proved to be moderately fast and very stable. It will provide the platform for future teams to outfit with improved electrical/solar equipment and engines for future competitions.

Performance of the USCG 47' Motor Life Boat Based on Methods of Prediction, Model Testing, and Full Scale Trials

Researcher: Midshipman 1/C Jon S. Erskine, USN
Advisers: Professor Bruce C. Nehrling and Professor Gregory J. White

Prior to the construction of a new class of vessels, designers perform model tests in order to predict the performance characteristics of the full-scale vessel as accurately as possible. This helps the designers ensure that the boat will meet the

criteria set forth in the mission requirements. Once the full-scale production unit is built and tested, rarely if ever are the full-scale trail results compared with the performance data predicted by the model testing.

In the case of the U. S. Coast Guard's 47' Motor Life Boat, a unique opportunity existed. The Naval Academy's Hydromechanics Laboratory was able to obtain the original model used to do the performance prediction, and the data from the builder's trials of MLB 47206, which was the first production boat delivered by TEXTRON Marine & Land Systems Division. The test plan for this project was laid out with the intent of being able to compare the SHP and trim obtained from the full-scale trials data with the results of scale model testing and to compare both to computer predictions based on the methods developed by Daniel Savitsky and J.B. Hadler. The model was updated to reflect the configuration of MLB 47206 at the time of the builder's trials and a series of bare hull EHP tests were performed to cover the range of speeds and conditions of the builder's trials.

The EHP data was combined with typical theoretical predictions for the propulsive coefficient based on the specified propeller to predict the SHP and trim. The results of this comparison showed that the model testing SHP calculations provided a fairly accurate match to the performance characteristics of a hull reported in the builder's trials before its production and subsequent builder's test. The computer-based predictions slightly over estimated the SHP at the lower speeds and then underestimated by nearly 17% at the maximum speed. Although the computer predictions were close for SHP, the method tended to greatly overestimate the trim values at all but the maximum speed.

Effect of Sanding on the Performance of Lifting Surfaces

Researcher: Midshipman 1/C Christian Esquivel, USN (Oceanography Major)
Adviser: Assistant Professor Michael P. Schultz

An experimental investigation has been carried out to document and relate the drag, lift, and roughness texture of a painted lifting surface smoothed by sanding. Aerodynamic tests were carried out on a Laser centerboard (NACA 0008 with 22° sweep) in a closed circuit wind tunnel at Reynolds numbers of 5.0×10^5 and 1.0×10^6 based on the chord length and freestream velocity. Results indicate no change in the drag and lift coefficient within the experimental uncertainty over most of the angle of attack (a) range. The roughness delayed stall and increased the lift coefficient at the higher a range. However, these differences were noted well beyond the range of what would be typically encountered while sailing.

Publications

Journal (Refereed) Manuscripts

ARVIDSON, Mark H., Midshipman 1/C, (USN) and MILLER, Paul H., Assistant Professor, "Hull Material Evaluation for Navy 44 Sail Training Vessel," *Naval Engineers Journal*, Vol 113, No. 2, pp.71-78 (2001).

Material characterization tests were performed at the US Naval Academy to identify a toughened laminate for the new Navy 44-foot sail training vessels. After preliminary analysis using classical lamination theory, four different cores, five laminates and seven resin systems were tested in UV exposure, four-point bending, lateral panel pressure, and simulated bow impact. Results showed substantial improvements in strength, toughness, cost and weight were possible over the existing laminate, with the lightest acceptable laminate yielding a weight savings equivalent to 3.5% of the vessel's displacement.

DAWSON, T.H., Professor, "Markov Theory for Groups of Very High Waves," *International Journal of Offshore and Polar Engineering*, Vol 12, No. 2, June 2002, pp. 1-4.

Statistics of wave groups among very high waves are examined using Markov theory and data from wave records developed by computer simulations of a Jonswap 3.3 sea. Very high waves are considered to be those with threshold heights exceeding the significant wave height by 10% or more. Theory indicates decreased group formation

among the very high waves as a result of decreased Markov correlation between waves. Data confirm the prediction and provide additional insight into the group phenomena.

Finlay, J.A., Callow, M.E., SCHULTZ, M.P., Assistant Professor, Swain, G.W., and Callow, J.A., "Adhesion Strength of Settled Spores of the Green Alga *Enteromorpha*," *Biofouling*, Vol 18, pp. 251-256 (2002).

Strengths of attachment of spores of the green fouling alga *Enteromorpha* to glass have been measured using a modified water jet apparatus. Surface pressures of ~100 kPa were required to remove 50% of attached spores after 4 h contact with a surface. The development of adhesive and cohesive strength is highly time-dependent: after 8 h in contact with a surface spores did not detach even at pressures in excess of 200 kPa. Spores settled in groups are more resistant to detachment than single spores. The interfacial forces exerted as water impinges on the surface and the derivation of adhesion strength values in terms of wall shear stress are discussed and compared with those obtained by other methods.

Kavanagh, C.J., SCHULTZ, M.P., Assistant Professor, Swain, G.W., Stein, J., Truby, K., and Wood, C.D., "Variation in Adhesion Strength of *Balanus eburneus*, *Crassostrea virginica* and *Hydroides dianthus* to Fouling-Release Coatings," *Biofouling*, Vol 17, No. 2, pp.155-167 (2002).

This study compared the shear adhesion strength of barnacles, oysters and tubeworms on eight RTV 11-based silicone fouling-release coatings containing different silicone oil additives. It was found that adhesion strength differed among species and coating types. In most cases, oysters and tubeworms had higher adhesion strength than barnacles. Barnacle adhesion strength was reduced on all coatings containing oil additives; however, this was not generally true for oysters and tubeworms. The difference in the adhesion strength among the three organisms tested in this study emphasizes the importance of understanding the fundamental interaction between marine invertebrate adhesives and the substrate.

MILLER, Paul H., Assistant Professor, "Effects of Moisture Absorption and Test Method on the Properties of E-glass / Polyester Hull Laminates," *Journal of Composite Materials*, Vol 38, No.4, pp. 278-292 (2001).

Effects of moisture absorption on the tensile, compressive, shear, bending and bending fatigue properties of an iso-polyester/E-glass hull laminate were studied. Fickian diffusion constants were found that closely modeled moisture absorption. Comparisons were made of standard moisture experiments using boiling water versus long-term exposure. Results indicated the boiling water test yielded significantly conservative values. Fatigue endurance limits were found to be near 25% of static load, indicating a fatigue design factor of four is required for infinite service with this material. Coupon results were used with finite element analysis (FEA) to predict panel deformations and strains. Good correlation was achieved.

MILLER, Paul H., Assistant Professor, "Fatigue Prediction Verification of Fiberglass Hulls," *Marine Technology*, Vol 36, No. 9, October 2001, pp. 1065-1078.

The growing use of marine composite materials has led to many technical challenges, including predicting lifetime durability. Analytical models based on classical lamination theory, finite element analysis, ship motions, probability and wind and wave mechanics were used in this project to predict hull laminate strains and fatigue tests were used to determine S-N residual stiffness properties of coupons. These predictions and test data were compared against two cored fiberglass sisterships having significantly different fatigue histories and undamaged laminates representing a new vessel. Strains were measured while underway and good correlation was achieved between predictions and measurements. Fatigue damage indicators were identified which could be used in vessel inspection procedures. Endurance limits were found to be near 25% of static failure load. A rational explanation for using thicker outer skin laminates in marine composites was identified through single-sided moisture flex tests. These showed that the reduced strength and stiffness due to moisture of the outer hull skin laminate could be compensated by increased thickness.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor, and SIMMONS, D. Kevin, (Trident Scholar, Class of 1999), "Reinforced Concrete Beams Externally Retrofitted with Advanced Composites," *Advanced Composite Materials Journal*, Vol. 10, No. 2-3, 2001, pp.139-146.

This study investigates the effect of externally bonded carbon fiber reinforced polymer (CFRP) laminates on the ductility of reinforced concrete beams used in the repair of damaged bridge structures. Reinforced concrete structures deteriorate over time due to environmental aging, fatigue, excessive loading, chemical attack, and other factors. Strengthening and rehabilitating these concrete structures by externally bonding carbon laminates is one of many economical engineering solutions. Eight rectangular beams with varying internal steel reinforcement were retrofitted with CFRP strips on the tension faces and tested under four-point bending. The beams were instrumented to monitor strains, deflection, and curvature over the entire spectrum of loading, and determine the structural response of the beams. An existing analytical model using the discrete yield and ultimate values of the load-deflection and moment-curvature curves was modified to an energy-based model, and used to predict the ductility of the beams. Numerical results indicated an increase in strength, a decrease in ductility, and validated the analytical model. Ultimately, this study will aid in the development of design guidelines governing the use of CFRP.

NUCKOLS, M. L., Professor, "Naval Forces Under the Sea: A Look Back, A Look Ahead," *Sea Technology*, November 2001, pp. 42-46.

The "Naval Forces Under the Sea" Symposium was, first and foremost, to capture and preserve the historical base of knowledge in this discipline that in many cases resided only in the minds of the primary contributors in this area. The primary activity for each day was a series of presentations and panel discussions on the topic of the day. Operational, technical and medical communities all participated in these proceedings since none could have existed in these interdisciplinary topic areas without the other two. Secondary activities included live demonstrations, oral histories and group interviews, as well as static equipment displays.

The "Naval Forces Under the Sea" Symposium attracted a world–renowned cast of speakers, including Assistant Secretary of the Navy David Oliver, the Chief of Naval Research Rear Admiral Jay M. Cohen, and best-selling author Peter Maas, just to mention a few. In addition over 30 exhibitors representing all walks of the undersea warfare communities presented static displays depicting both past and present equipment and capabilities. Daily live demonstrations by Explosive Ordnance Disposal (EOD) divers, SEAL Teams, the Navy SEAL parachute demonstration team LEAPFROGS, and ship visits by the salvage ship USS GRASP and SEAL support ship USS TORNADO rounded out the three-day program. Running concurrently with these daily activities were behind-the-scenes oral history recordings by the Naval Historical Center, interviews by local and national news media, and selected book signings, including *The Terrible Hours* (Peter Maas), *Sea Dwellers* (Bob Barth), and *The Silent War* (John Craven).

The 3-day symposium addressed one of three primary topics each day in historical order of occurrence: including submarine rescue, special warfare, and Navy diving and salvage.

Saylor, J.R., FLACK, K.A., Associate Professor, SCHULTZ, M.P., Assistant Professor, and Smith, G.B., "The Correlation between Surface Temperature and Subsurface Velocity during Evaporative Convection," *Experiments in Fluids*, Vol. 32, No. 5, 2002, pp. 570-579.

Correlation coefficients between measurements of temperature at a water surface and velocity at a location beneath the water surface undergoing evaporative convection are presented. The surface temperature measurements were obtained via quantitative infrared imaging and the velocity measurements were obtained using a two-component LDV system. The water surface was covered with a surfactant monolayer which did not impede evaporation. The largest measured correlation coefficient was 0.375. Correlation coefficients obtained after shifting the velocity and temperature traces with respect to each other revealed a peak in the correlation coefficient very close to a zero time shift. The significance of these results and their implications for the remote sensing of underwater objects via infrared imaging are discussed.

SCHULTZ, Michael P., Assistant Professor, Finlay, J.A., Callow, M.E., and Callow, J.A., "Three Models to Relate the Detachment of Low Form Fouling at Laboratory and Ship Scale," *Biofouling*, Vol 19 Supplement, pp. 17-26 (2002).

Since fouling-release coating systems do not prevent settlement, various methods to quantify the tenacity of adhesion of fouling organisms on these systems have been offered. One such method is the turbulent channel flow apparatus (Schultz *et al.*, 2000). The question remains how the results from laboratory scale tests relate to the self-cleaning of a ship coated with a fouling-release surface. The present paper relates the detachment strength of low form fouling determined in the laboratory using a turbulent channel flow to the conditions necessary for detachment of these organisms in a turbulent boundary layer at ship scale. A power-law formula, the ITTC-57 formula, and a computational fluid dynamics (CFD) model are used to predict the skin-friction at ship scale. The results from all three methods show good agreement and are illustrated using turbulent channel flow data for sporelings of the green macrofouling alga *Enteromorpha* growing on a fouling-release coating.

SCHULTZ, M.P., Assistant Professor, "The Relationship between Frictional Resistance and Roughness for Sanded Surfaces," *Transactions of the American Society of Mechanical Engineering* (*ASME) Journal of Fluids Engineering*, Vol 124, pp. 492-499 (2002).

An experimental investigation has been carried out to document and relate the frictional resistance and roughness texture of painted surfaces smoothed by sanding. Hydrodynamic tests were carried out in a towing tank using a flat plate test fixture towed at a Reynolds number (Re_L) range of $2.8 \times 10^6 - 5.5 \times 10^6$ based on the plate length and freestream velocity. Results indicate an increase in frictional resistance coefficient (C_F) of up to 7.3% for an unsanded, as-sprayed paint surface compared to a sanded, polished surface. Significant increases in C_F were also noted on surfaces sanded with sandpaper as fine as 600-grit as compared to the polished surface. The results show that, for the present surfaces, the centerline average height (R_a) is sufficient to explain a large majority of the variance in the roughness function (ΔU^+) in this Reynolds number range.

SCHULTZ, M.P., Assistant Professor, and FLACK, K.A., Associate Professor, "Effect of Strake Geometry and Centerbody on the Lift of Swept Wings," *American Institute of Aeronautics and Astronautics (AIAA) Journal of Aircraft*, Vol 39, No. 2, pp. 377-379 (2002).

Modern fighter/attack aircraft rely on vortex flow to increase lift at moderate to high angle-of-attack ($a\delta$). Therefore, a great deal of interest exists in understanding and predicting the vortical flow structure generated by swept wings. One form of vortex control uses small geometry modifications (fillets) at the strake-wing junction to alter the vortex dynamics. Fillets are also possible candidates for roll control devices, being deployed symmetrically for enhanced lift and longitudinal control, or asymmetrically for lateral-directional control. The primary objective of the present experiment was to investigate the lift characteristics of fillets of a three-dimensional model and compare the results to a flat-plate model with the same planform. It was also hoped to experimentally validate and quantify the increase in lift as a result of fillets on flat-plate models with the same planform as the three-dimensional model. A secondary objective was to evaluate the effect of a simple centerbody on the lift of flat-plate models with and without fillets as a means for comparison to the full three-dimensional model.

Conference Proceedings

DAWSON, Thomas H., Professor, "Rayleigh Law and Stokes Correction for High Waves in Heavy Seas," *American Society of Civil Engineers* (*ASCE) Proceedings of Fourth International Symposium on Ocean Wave Measurement and Analysis*, San Francisco, September 2001, pp. 484-493.

Stokes 5th order wave theory is used to modify the Rayleigh probability law for random deepwater waves. Results show that predictions differ sensibly form those based on 2nd order theory for high waves in heavy seas where crest amplitudes equal or exceed the significant wave height and where wave heights equal or exceed twice the significant wave height. Predictions are shown to be in good agreement with published field measurements.

FINLAYSON, W.S., Lieutenant Commander, (USN) and NUCKOLS, M.L., Professor, "An Alternative Rebreather Design Concept that Couples Gas Injection to Respiratory Rate," *Proceedings of Underwater Intervention 2002*, Feb 27-March 2, 2002, New Orleans, LA, (CD-ROM Paper J-2-2)

A model for a mechanically coupled, respiratory proportional mass injection, semi-closed circuit underwater breathing apparatus is presented. Such an apparatus would allow precise control of system oxygen levels without the use of a microprocessor, using much less gas than current respiratory-coupled systems. A proof of concept regulator was designed and built using the concept of a variable injection area sonic orifice. By coupling the injection area of the sonic orifice to the diver inhalation rate, the regulator achieves the proportional mass injection required. A simple system was tested using the regulator to show agreement with the model. Good agreement was established which proves the concept and opens the door for mass coupled semi-closed systems which result in very predictable oxygen levels with very small gas consumption.

FINLAYSON, W.S., Lieutenant Commander, (USN), NIGGEMANN, R., Midshipman 1/C, (USN) and NUCKOLS, M.L., Professor, "Optimization of Variable Volume Exhaust Semi-Closed Underwater Breathing Apparatus," *Proceedings of Oceans 2001*, 5-8 November 2001, Honolulu, HI, pp. 1731-1734.

The performance of variable volume exhaust (VVE) rebreathers are characterized by an exhaust volume ratio (EVR), the ratio of the small inner bellows volume relative to the main breathing bellows, and supply gas oxygen concentrations (XO_2). This paper details the development of the approach used to enhance the performance of these systems. An analytical model has recently been developed for predicting the circuit oxygen levels in variable volume exhaust semi-closed underwater breathing apparatus at various mission depths and diver activity levels. Unmanned testing in June 2000 with a commercially available system showed good agreement with this analytical model over a wide range of diver depths, orientations and activity levels. The analytical model showed that for given operational parameters of maximum and minimum depth there must be an optimum EVR and XO_2 which will maximize capability while ensuring allowable maximum and minimum partial pressures of oxygen (PO_2) in the breathing circuit. By specifying boundary conditions on the analytical model at maximum and minimum depth for the associated allowable minimum and maximum PO_2 an analytical relationship for EVR and XO_2 was developed and subsequently validated in unmanned testing at the Experimental Diving Unit in Panama City, FL. Associated EVR and XO_2 are presented for three missions of possible interest to the Navy; shallow depth (<60 FSW), deep depth (<190 FSW) and a switch over to closed circuit at very shallow depth (20 FSW). Gas consumption comparison to open circuit SCUBA is also made for each of these mission profiles.

KRIEBEL, David L., Professor, "Wave Amplification and Air Gap Tests on a MOB Module," *Proceedings of the 24th US-Japan Marine Facilities Panel, US-Japan Cooperative Program in Natural Resources*, Honolulu, HI, Nov 2001. (Available at www.dt.navy.mil/ip/mfp/24th_Papers-US.html)

This paper summarizes physical model tests conducted on a large semi-submersible model, representing a 1-to-70 scale model of one module of the U.S. Navy's proposed Mobile Offshore Base (MOB), to evaluate the degree of

wave amplification that can occur under semi-submersible hull. This paper discusses the characteristics of the MOB module, the experimental setup and test conditions, the resulting measurements of platform motions, and the amplified wave elevations measured at nine locations under and around the model.

KRIEBEL, David L., Professor and FINLAYSON, W.S., Lieutenant Commander, (USN), "Ocean Engineering Design Experience at the U.S. Naval Academy," *Proceedings of the Oceans 2001 Conference*, pp. 608-612, Honolulu, HI, Nov 2001.

This paper presents an overview of the capstone design course in the undergraduate ocean engineering curriculum at the U.S. Naval Academy. The emphasis of this course is on integrating "real-world" design problems and design procedures into the academic curriculum to benefit the students as well as public sector "clients" who volunteer their time to mentor students. Examples of recent projects are given in the paper, and several are highlighted as case studies to show how student design can lead, after additional professional design effort, to completed constructed projects.

JOYCE, Peter, Assistant Professor, BARTON, Oscar, Jr., Associate Professor, and MOURING, Sarah E., Associate Professor, "Evaluation of the Effect of Impact Damage on the Mechanical Response of Composite Sandwich Structures," *American Society for Composites 16th Annual Technical Conference Proceedings*, Blacksburg, VA, September 2001, Paper 128, Session MA5. (CD-ROM)

This research seeks to evaluate the effect of impact damage on the mechanical response of composite sandwich structures. The sandwich panels in this investigation are under consideration for aerodynamic structural applications. A total of twenty-four panels, with varying levels of impact damage, were tested including four control panels containing no impact damage. The remaining twenty specimens were grouped according to the size of the impactor, which varied from, 0.5 in. to1 in. diameter and impact energy. The impact energy levels consisted of 6 ft-lbs, 20 ft-lbs, and 35 ft-lbs, representing relatively low, moderate, and high impact energy levels. Properties investigated included the compressive strength and elastic stiffness. Each panel was manufactured using fiber placement technology. Each panel was made with astro-quartz upper and lower face sheets and a honeycomb core using IM977-3 resin. The stacking sequence of each face sheet was given as [30/-30/0/-30/30] and has a total thickness of 0.032 inches. Test results show that both impact energy level and impactor size affect the compressive strength and failure mode of the panel specimens. The compressive strength decreases with an increase in impactor size and/or impact level. Catastrophic shear cracking is associated with low impact levels whereas progressive shear cracking is associated with medium impact levels.

MAYER, Robert H., Associate Professor, and WATERS, Jennifer K., Associate Professor, "Optimal Plans and Costs for Maintenance Dredging Operations," *Proceedings of the Conference 'Dredging 2002,'* American Society of Civil Engineers, Orlando, FL, May 2002. (CD-ROM Track 4E)

An adaptation of the classical inventory system model of operations research is suggested for planning and scheduling maintenance dredging operations in navigation channels. In the sediment inventory model (SIM) that results, the costs of periodic and advance maintenance dredging are set against the economic and safety implications of sediment encroachment into the channel. Among SIM variations, the situation when sediment rates are constant and dredging costs reasonable to predict, optimal dredging plans, costs and schedules may be determined by mathematical techniques such as differential calculus. Properly formulated, the resulting SIM models yield least-cost solutions and also reveal optimal relations between competing costs and alternative criteria such as safety and navigation efficiencies. When sediment rates are probabilistic and dredging costs uncertain, the stochastic SIM variant may provide useful insights into appropriate dredging policies and risks of encroachment. Through examples, this paper illustrates the results of the basic SIM variants as they apply to maintenance dredging, and suggests extensions and limitations of the model to such complexities as lead-time scheduling of dredging equipment.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Associate Professor, and SIMMONS, D. Kevin, (Trident Scholar, Class of 1999), "Investigation into the Structural Behavior of Reinforced Concrete Beams Externally Retrofitted with Carbon Fiber Reinforced Polymer Composites," *2001 Second International Conference on Engineering Materials Proceedings*, San Jose, CA, pp. 409-418, August 2001, in print.

This study investigates the structural behavior of reinforced concrete beams externally retrofitted with carbon fiber reinforced polymer (CFRP) laminates. More specifically, the effects on strength and ductility are of major importance. Eight rectangular beams with varying internal steel reinforcement were retrofitted by externally bonding CFRP laminates onto the tension faces and tested under four-point bending. Each beam was instrumented to monitor deflection, curvature, and strain over the entire loading spectrum, and to determine its structural response. A modified energy-based model is used to predict ductility. Results from this research indicate a decrease in ductility, an increase in strength, and validate the modified analytical model.

MOURING, Sarah E., Associate Professor, "Behavior of Composite Sandwich Panels Subjected to Impact Damage," *NSF Civil and Mechanical Systems Conference Proceedings*, Arlington, VA, October 2001. (Published as a collection of papers)

Research was performed to determine the compression strength of composite sandwich panels subjected to drop-weight impact damage (ONR-sponsored research). Twenty four panels were tested including four control panels containing no impact damage. The remaining twenty specimens had varying levels of impact damage and were grouped according to impactor size, 0.5 in and 1.0 in diameter, and impact energy level. The impact energy levels were 6 ft-lbs, 20 ft-lbs, and 35 ft-lbs and represent relatively low, moderate, and high impact energy levels, respectively. The effect of impact damage on the behavior of composite sandwich structures was evaluated from these tests. Results show that both impact energy level and impactor size affect the compressive strength and failure mode of the panel specimens. The compressive strength decreases with an increase in impactor size and/or impact level. Catastrophic shear cracking is associated with low impact levels whereas progressive shear cracking is associated with medium impact levels.

MOURING, Sarah E., Associate Professor and Reichard, R., "Fabrication of a Composite Superstructure using a New Assembly Method," *The 11th International Offshore and Polar Engineering Conference Proceedings*, Stavanger, Norway, June 2001, Vol. IV, pp. 218-221.

A composite superstructure system has been developed recently as part of a MARITECH program. In the fall of 1999, a technology demonstration superstructure was fabricated at Ingalls Shipbuilding in Pascagoula, MS, USA. The superstructure was two stories high with a 20 ft by 30 ft footprint, and was fabricated from flat fiber-reinforced polymer (FRP) sandwich panels, FRP angles, FRP bonding plates, and FRP frames. A new adhesive bonding technique was chosen as the adhesive assembly method. Results from this project demonstrate that both military and commercial superstructure geometries can be constructed using simple components. This paper will outline the fabrication procedure of the composite superstructure system including a discussion on the ongoing development and evaluation of the new joining technique.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor, and SIMMONS, D. Kevin, (Trident Scholar, Class of 1999), "External Retrofit of R.C. Beams using CFRP Laminates," *Ninth International Conference on Structural Faults and Repair – 2001Proceedings*, London, UK, July 2001. (CD-ROM)

The structural behavior of reinforced concrete (RC) beams externally retrofitted with carbon fiber reinforced polymer (CFRP) laminates is investigated in this study. Deterioration of RC structures has become a serious problem as a result of the corrosion of internal steel reinforcement. Many solutions have been proposed to remedy this problem, ranging from replacement of the structure to strengthening with a variety of techniques. One such strengthening technique is to bond CFRP laminates externally to deteriorating RC structures. As part of this study, eight rectangular beams with varying internal steel reinforcement were loaded under four-point bending past initial cracking of the tension face to simulate service damage. Subsequently, all except the control beam were repaired in-situ by externally bonding CFRP laminates onto the tension faces and tested to failure under the same

loading conditions. The beams were instrumented to monitor deflection, curvature, and strains over the entire loading spectrum, and determine the structural response of each beam. Ductility indices were determined for each beam using an energy-based ductility model. This energy-based model was developed from an existing analytical model that used discrete yield and ultimate values from the moment-curvature and load-deflection curves. Numerical results indicate a decrease in ductility, an increase in strength, and validate the modified ductility model. This research demonstrates the feasibility of strengthening RC beams with externally bonded CFRP laminates.

MOURING, Sarah E., Associate Professor (co-author), "Glass and Glass/Carbon Fiber Hybrid Composites in Submerged Load Bearing Structures," *Composites 2001 Proceedings*, Tampa, FL, October 2001. (CD-ROM)

This work explores the design and fabrication of a unique underwater load bearing structure. The Hydromechanics Laboratory at the United States Naval Academy (USNA) Annapolis, MD requires a submerged structure in a 40:1 scale wave tank for simulating shallow water conditions. The structure will be subject to high dynamic loads from water waves, and the only support allowed requires tying into the tank wall every four feet. In addition, the structure must be easily installed without the use of heavy equipment.

During this project, pultrusion was used as a cost effective method of producing underwater load bearing structures. Glass fiber reinforced composite materials are used in the most parts; but when higher strength is desired, glass/carbon fiber hybrid composites are used.

NUCKOLS, M.L. Professor, Newville, B., and FINLAYSON, W.S., Lieutenant Commander, (USN), "Comparison of Predicted and Measured Oxygen Levels in a Semi-Closed Underwater Breathing Apparatus," *Proceedings of Oceans 2001*, 5-8 November 2001, Honolulu, HI, pp. 1725-1730.

An analytical model has recently been developed for predicting the circuit oxygen levels in semi-closed underwater breathing apparatus at various mission depths and diver activity levels (Nuckols, Clarke, Marr, 1999). Unmanned testing in June 2000 with a commercially available U.S. Divers Aqualung OxyMix rebreather (NEDU Test Plan Number 00-06 dated May 2000) showed good agreement with this analytical model over a wide range of diver depths, orientations and activity levels (Nuckols, Gavin, Finlayson, 2000). However, the model indicated that an enhanced performance capability could possibly be achieved with the OxyMix by modifying the size of its exhaust bellows and changing the oxygen content of the supply gas. Following the tests in June, an optimization approach was applied to the analytical model to define desired design parameters for the OxyMix rebreather to maximize its excursion depth capability. Optimized exhaust volume ratios (EVR), the ratio of the small inner bellows volume relative to the main breathing bellows, and supply gas oxygen concentrations were identified to maximize safe operations for the OxyMix design. US Divers agreed to fabricate two modified exhaust bellows of varying volumes for testing to verify the predicted performances of the modified OxyMix rebreather. During the week of 18 December 2000, unmanned testing with these modified OxyMix rebreathers at the Experimental Dive Facility at NEDU verified predicted performances. Specific findings in these tests included:

a) a modified OxyMix rebreather using an exhaust volume ratio of approximately 6.25% and a supply gas mixture containing 37% oxygen was shown to give an excursion capability to 130 FSW while maintaining circuit PO_2 levels below 1.32 Ata (excursions to 150 FSW were shown to be possible with maximum PO_2 levels below 1.6 Ata)

b) similar to the results seen in the June tests, circuit PO_2 levels were shown to be unaffected by diver activity rates between RMV's of 22.5 LPM and 62.5 LPM

c) the addition of a diluent injection system on the modified OxyMix design provided minimum circuit oxygen levels of 0.42 Ata at 20 FSW and 0.25 Ata at 0 FSW while still maintaining circuit PO_2 levels below 1.32 Ata for excursions up to 130 FSW.

NUCKOLS, M.L., Professor, Vanzandt, K.W., and FINLAYSON, W.S., Lieutenant Commander, (USN), "Evaluation Of A Diver Heater Using Hydrogen Catalytic Reactions," *Proceedings of Undersea and Hyperbaric Medical Society Meeting*, June 2001, San Antonio, TX, Vol 28 (2001 Supplement), p. 82.

A concept assessment was recently conducted to determine the feasibility of using a hydrogen catalytic heater in conjunction with closed-circuit hot water suits as a heat source for divers in swimmer delivery vehicle (SDV) applications. A laboratory prototype heater using a semi-closed circuit design was tested in the Hydrospace Laboratory at the Coastal Systems Station in Panama City, FL during July 2000 to prove concept feasibility. The objective of this unmanned test series was to assess the performance of a laboratory prototype catalytic heater which releases thermal energy when passing air mixed with up to 1% hydrogen, by volume, through a catalyst bed consisting of extruded carbon pellets coated with 0.8 wt% palladium. Major findings in this test series included the following: a) Confirmed that 1% hydrogen mixed in 100 psi air is adequate to produce over 2000 watts of heat (sufficient heat for 6 divers); b) The prototype heater is capable of delivering up to 6 gpm water flow rate at 100-102 F; c) Near 100% heating efficiency was achieved with the existing prototype heater; d) Hydrogen consumption rates of only 25 standard cubic feet (SCF) per hour is sufficient to deliver the desired heating level of 2 KW; e) Heat levels can be easily predicted and controlled; f) Start up and operation of catalyst bed does not appear to be affected by cold temperatures; and g) No pre-conditioning of the catalyst was found necessary.

NUCKOLS, M.L., Professor and Henkener, J.A., "Thermal Protection of Diver Extremities By Use of Insulating Fluids," *Proceedings of Undersea and Hyperbaric Medical Society Meeting*, June 2001, San Antonio, TX, Vol 28 (2001 Supplement), pp. 82-83.

An inert, pourable liquid insulating medium consisting of a mixture of halocarbon oils, glass micro-spheres, and suspension-enhancing additives has been developed which provides superior thermal protection for divers' gloves and underwater cabins (chambers, submersible hulls, waterproof housings, etc). Two glove prototypes were recently designed and fabricated incorporating this liquid insulation medium. These glove prototypes were compared with commercial wet and dry gloves in thermal performance, tactile sensitivity and manual dexterity. Preliminary tactile sensitivity and manual dexterity comparisons between the liquid glove prototypes and commercial divers' gloves were evaluated using a battery of specially designed test apparatuses and test procedures. Hand calorimeter testing at the Naval Clothing and Textile Research Facility in Natick, MA confirmed that glove insulation levels comparable to commercial three-fingered dry gloves are achievable with the addition of approximately 400 ml of liquid insulation. The insulating medium was found to be neutrally buoyant in water (specific gravity, SG, of 1.0), eliminating the necessity for ballasting and, unlike conventional closed-cell foam or fibrous batt insulations, is not thermally degraded by compression at elevated hydrostatic pressures. The insulating medium can be custom engineered to provide the desired level of thermal protection by varying the additives in the fluid. When this liquid insulation medium is mixed with approximately 45 vol% hollow, glass micro-spheres thermal conductivity, K, values comparable to those of uncompressed foam neoprene were achieved. A colloidal clay additive keeps the glass micro-spheres in liquid suspension in the halocarbon/glass mixtures.

NUCKOLS, M.L., Professor, and Vanzandt, K.W., "Design of an Oxygen Metabolic Simulator For Use In Unmanned Testing of Underwater Breathing Apparatuses," *Proceedings of Underwater Intervention 2002*, Feb 27-March 2, 2002, New Orleans, LA. (CD-ROM Paper J-2-3)

Currently, a complex system is used to simulate human metabolic consumption of oxygen during unmanned testing of closed and semi-closed circuit breathing apparatuses. Testing at the Navy Experimental Diving Unit in Panama City, FL uses a computer controlled technique that simulates diver oxygen consumption by extracting a portion of the oxygen-rich rebreather circuit gas volume and replaces it with an inert gas.

Extremely accurate gas flow rates must be measured and controlled through feedback control loops with this existing simulation method. In contrast, a simple oxygen "metabolizer" will be discussed in this paper that uses hydrogen catalytic reactions to accurately simulate oxygen consumption by injection of a hydrogen and carbon dioxide mixture into a catalyst bed integrated into a mechanical breathing simulator. The micro-metered hydrogen/CO_2 injection reacts with oxygen contained in the breathing circuit to simulate the desired diver activity level. The hydrogen injection rate is set to "consume" the desired quantity of oxygen to simulate diver activity level.

The carbon dioxide injection rate is set to simulate the desired metabolic respiratory quotient (RQ). By-products of water vapor and heat from the hydrogen/oxygen reaction further simulate heat and humidity transfer in the diver's lungs.

NUCKOLS, M.L., Professor, and Henkener, J.A., "Liquid-Insulation Garments For Long-Duration, Cold Water Diving," *Proceedings of Underwater Intervention 2002*, Feb 27-March 2, 2002, New Orleans, LA, (CD-ROM Paper G-2-3)

A suit liner containing a liquid insulation medium is being developed for the U.S. Navy to supplement the insulation value of divers' drysuits or wetsuits. The liquid medium base consists of an inert, pourable mixture of a medium molecular weight polymer of chlorotrifluoroethylene (PCTFE), which is environmentally safe, chemically inert and nonflammable. The liquid insulation was designed to be neutrally buoyant in water (specific gravity of 1.0), minimizing or eliminating the necessity for ballasting and, unlike conventional closed-cell foam or fibrous batt insulations, is not thermally degraded by compression at elevated hydrostatic pressures. Although a liquid, thermal conductivity values for the liquid mixture are comparable to those of uncompressed foam neoprene. This paper discusses the initial development of the liquid insulating medium and presents results of thermal testing of suit liner prototypes used with wetsuits and drysuits. Preliminary results suggest that a suit liner containing as little as ¼-inch thick layer of this insulating liquid can increase the insulating value of a diver's garment by as much as 0.5-0.6 CLO. A typical drysuit, with an inherent insulation value of 1-1.2 CLO, could be increased to 1.5-1.8 CLO. A typical wetsuit, with an inherent insulation value of 0.75 CLO, could potentially be increased to 1.25-1.35 CLO.

WATERS, Jennifer K., Associate Professor, and WHITE, Gregory J., Professor, "The Development Of An Archive of Naval Architecture and Ocean Engineering Laboratory Experiments," *American Towing Tank Conference*, Webb Institute, Glen Cove, NY, 23-24 July 2001. (Published as individual papers.)

Physical model tests are an invaluable asset to naval architecture and ocean engineering research, development and education. However, the actual value of laboratory testing depends not only on the physical plant and technology available, but also on the experience and expertise of the users. Recognizing this, the authors have undertaken a three-year effort to develop a high-quality record of numerous laboratory experiments performed within several naval architecture and ocean engineering courses at the U.S. Naval Academy (USNA).

The archive includes more than a dozen experiments performed in the Hydromechanics Laboratory at USNA, ranging from ship maneuvering to sediment transport studies. Each experiment record includes background information, experimental setup descriptions and details, data records with analyses, as well as high-quality photos and video recordings of the experiments underway. An archive of this depth and quality has never been assimilated and it is anticipated that the naval architecture and ocean engineering community both inside and outside USNA will be able to reap many benefits from it. In order to provide widest and easiest access to the work, a website is being created so as to make all of the products are accessible via the Internet. This paper discusses the project, its development, and some of the details of the results obtained.

WATERS, Jennifer K., Associate Professor, MAYER, Robert H., Associate Professor, and KRIEBEL, David L., Professor, "Dredging-related Implications of Current and Future Trends in the International Shipping Industry," *Proceedings of the Conference 'Dredging 2002' of the American Society of Civil Engineers*, Orlando, FL, May 2002. (CD-ROM Track 3A)

A National Dredging Needs Study (NDNS) was initiated by the Institute of Water Resources (IWR) of the USACE to investigate the adequacy of U.S. navigation channels and harbors to accommodate changes in the world merchant fleet well into the 21st century. Among the results of the NDNS was a projection of future vessel types and sizes calling at U.S. deep-draft ports, and an analysis of potential dredging needs based on these future traffic projections. A concurrent IWR study included a shipping trends impact assessment on navigation channel usage and design, based in part on the NDNS projections. This paper reviews and augments the NDNS projections with respect to changing vessel characteristics and ship designs, and discusses their impact on navigation channel design, maintenance, and the related dredging implications.

For example, there is a clear trend evident that vessel beam dimensions are increasing faster than vessel dimensions such as length or draft. The corresponding larger beam-to-draft ratios of transit vessels impact channel width and alignment to a greater extent than channel depths. As a result, required dredging quantities are increasing at a greater rate than dredging depths. Understanding the impacts of changing vessel characteristics and designs on channel geometry and dredging requirements is critical to navigation design and maintenance planning.

Patents

NUCKOLS, M. L., Professor, PELSTRING, J.A., Midshipman 1/C, (USN), and STINESPRING, B.M., Midshipman 1/C, (USN), U. S. Patent #6,346,141, "Supplying Breathable Gas For An Underwater Habitat," awarded 12 Feb 2002.

A carbon dioxide absorption system is described which provides a safe and inexpensive means of removing metabolically-produced carbon dioxide from cabin gases in underwater habitats, submarines, or a wide range of diving applications. This carbon dioxide scrubber involves the direct absorption of carbon dioxide in small concentrations in diffused air by a seawater tower, either pressurized or unpressurized. The design offers a low-energy carbon dioxide scrubber to be externally or internally mounted on an underwater habitat, submarine or diving life support system which has no chemical replenishment or disposal requirements.

NUCKOLS, M.L., Professor, and FINLAYSON, W.S., Lieutenant Commander, (USN), U. S. Patent #6,408,847, "Rebreather System That Supplies Fresh Make-Up Gas According To A User's Respiratory Minute Volume," granted 25 June 02.

A new semi-closed circuit breathing apparatus design is disclosed which injects fresh makeup gas by mechanically coupling the injection rate of this makeup gas with a diver's respiratory minute volume (RMV). The invention maintains a constant oxygen fraction in the breathing circuit, similar to an open circuit SCUBA, while decreasing the gas supply requirements by up to 80% of that used in open circuit SCUBA.

Technical Reports

DAWSON, Thomas H., Professor, "Markov Theory for Groups of Very High Waves," *USNA Report EW-02-01*, July 2001.

Statistics of wave groups among very high waves are examined using Markov theory and data from wave records developed by computer simulations of a Jonswap 3.3 sea. Very high waves are considered to be those with threshold heights exceeding the significant wave height by 10% or more. Theory indicates decreased group formation among the very high waves as result of decreased Markov correlation between waves. Data confirm the prediction and provide additional insight into the group phenomena.

MAYER, Robert H., Associate Professor, WATERS, Jennifer K., Associate Professor, and KRIEBEL, David L., Professor, "Design and Maintenance of Deep-Draft Navigation Channels - A Comparison of Current Practice with U.S. and International Guidance," a document prepared in fulfillment of Milestone Number 7 of the USACE' R&D Work Unit entitled: Impacts of Navigation Trends on Channel Usage and Design, September 2001.

Among the vital missions of the U.S. Army Corps of Engineers (Corps) is the development and maintenance of inland and coastal waterways in support of commercial navigation. Currently, the Corps is responsible for maintaining and improving more than 200 deep-draft ports and harbors. In fulfillment of this responsibility, the Corps' Institute for Water Resources (IWR) has initiated a study entitled "Impacts of Navigation Trends on Channel Usage and Design." Its principal goal is to improve the design and maintenance of navigation channels in order to sustain effective channel navigation and port operations well into the next century.

As part of this study, the authors completed a literature review of current practices used domestically and internationally to design and maintain deep-draft navigation channels. Current state-of-the-art results were summarized in the report, "Design & Maintenance of Deep-Draft Navigation Channels: An Overview of Current Practice with an Annotated Bibliography." Corps design and maintenance guidance was later compared with other U.S. and international design and maintenance practices and the results summarized in a second report, " Deep-Draft Navigation Channel Design: A Comparison of U.S. and International Practice."

In a parallel effort, the authors aided another IWR contractor who interviewed Corps personnel regarding current channel design and maintenance policies as practiced within their organizations. Representatives from various Corps organizations including HQUSACE, divisions, districts, and WES, were interviewed. Within each organization, personnel from various functional areas such as planning, engineering, construction and operations, were represented. Responses to questions used in the interview process were subsequently analyzed and compared with existing Corps guidance as well as other domestic and international guidance. This report serves to document this comparison.

MILLER, Paul H., Assistant Professor, Eight technical reports written and distributed to design team members in support of research and testing for the Team Dennis Conner's America's Cup projects.

SCHULTZ, Michael P., Assistant Professor, "The Relationship between Frictional Resistance and Roughness for Sanded Surfaces," *Bulletin of the American Physical Society, 54th Annual Meeting of the Division of Fluid Dynamics*, Vol. 46, No. 10, 2002, pp. 105-106.

An experimental investigation has been carried out to document and relate the frictional resistance and roughness texture of painted surfaces smoothed by sanding. Hydrodynamic tests were carried out in a towing tank using a flat plate test fixture towed at a Reynolds number (Re_L) range of $2.8 \times 10^6 - 5.5 \times 10^6$ based on the plate length and freestream velocity. Results indicate an increase in frictional resistance coefficient (C_F) of up to 7.3% for an unsanded, as-sprayed paint surface compared to a sanded, polished surface. Significant increases in C_F were also noted on surfaces sanded with sandpaper as fine as 600-grit as compared to the polished surface. The results show that, for the present surfaces, the centerline average height (R_a) is sufficient to explain a large majority of the variance in the roughness function (ΔU^+) in this Reynolds number range.

SMITH, W., Midshipman 1/C, (USN), MOURING, Sarah E., Associate Professor, and BURKHARDT, John A., Assistant Professor, "Measurement of Constrained-Layer Damping," *EN496 Research Report*, May 2002.

Excessive noise is a common problem in the marine industry. There are many methods used for noise control. One such method is the application of constrained-layer damping to the structure. It is important that the correct amount of damping is applied. Too little and the noise is not significantly reduced, and too much and the system is overdamped. Therefore, it is important to optimize the amount of constrained-layer damping in a given system. In order to help in the optimization, a simple experimental test is needed to measure the damping level in a system with constrained-layer damping. The development of one such test is the focus of this research project. Experimental results are compared to theoretical results in order to evaluate the proposed method.

WATERS, Jennifer K., Associate Professor, MAYER, Robert H., Associate Professor, and KRIEBEL, David L., Professor, "Impacts of Navigation Trends on Channel Usage and Design: Findings and Recommendations," document prepared in fulfillment of the U.S. Army Corps of Engineers' R&D Work Unit entitled: Impacts of Navigation Trends on Channel Usage and Design, September 2001.

Among the vital missions of the U.S. Army Corps of Engineers (Corps) is the development and maintenance of inland and coastal waterways in support of commercial navigation. Currently, the Corps is responsible for maintaining and improving more than 200 deep-draft ports and harbors. In fulfillment of this responsibility, the Corps' Institute for Water Resources (IWR) initiated a study entitled "Impacts of Navigation Trends on Channel Usage

and Design." Its principal goal is to improve the design and maintenance of navigation channels in order to sustain effective channel navigation and port operations well into the next century.

The study has been comprised of three principal and interrelated components: (1) a safety performance review, (2) a channel design and maintenance assessment, and (3) a shipping trends analysis. In addition, an ambitious, comprehensive survey of Corps personnel involved in deep-draft navigation design and maintenance augmented and fed into each of the three aforementioned components. This document summarizes the findings and recommendations developed throughout the various phases of the study.

Various findings and recommendations are included in this document, covering subjects from policy to technical issues. The authors have aimed to be as objective and thorough as possible throughout the research, analysis and development of recommendations. Additional findings and further documentation may be found in the other supporting reports produced by the authors as part of the study.

WHITE, Gregory J., Professor and HARRIS, Nancy, Naval Architect (Hydro Lab), "Slow-Speed and Zero-Speed Seakeeping Model Tests of the 2200 LT MCM(XH) HYSWAS Hull Form," *USNA Report EW-03-01*, August, 2001.

A tank model test series has been performed for the specific purpose of measuring the low-speed seakeeping performance. The model was configured with foils to provide an accurate representation of the added-mass effects of these surfaces. The model was ballasted to reflect two different loading conditions, a light condition (2,000 LT) and a full load condition (2,200 LT). Measurements were recorded for pitch angle, pitch rate, roll angle, roll rate, heave acceleration, wave height, and forces at the top and bottom of the hull strut. Using this information, the roll and pitch accelerations and the bending moments on the strut were also determined. Tests were conducted for zero speed and slow speed (3 knots full scale) in sea state conditions 3, 4, 5, and 6. During the zero speed tests, runs were conducted with relative headings (to the waves) of 0, 30, 60, 90, 120, 150, and 180 degrees. All of the towed tests were conducted in head seas only, with the addition of a sea state 8 test run.

The HYSWAS model performed much as was expected during both test series. As can be seen in the results charts, the zero speed pitching motions were worse as the vessel approached head or following seas. The zero speed rolling motions worsened as the heading approached beam seas. There was some generally small reductions in the rolling and pitching motion at the heavier displacement in the Zero Speed tests. The bending moments determine from the force measurements were quit large and dramatically increased as the relative heading approached 90°.

Presentations

Berring, N., Murray, S., Lemay Center, Brailsford, B., WALLENDORF, Louise, Hydro Lab Ocean Engineer, and MOURING, Sarah E., Associate Professor, "Glass and Glass/Carbon Fiber Hybrid Composites in Submerged Load Bearing Structures," Composites 2001, Tampa, FL, October 2001.

Bigio, D., Schmidt, L., Schmidt, J., MOURING, Sarah E., Associate Professor, Wilkens, G., and Gloster, C., "Implementing the BESTEAMS Model of Team Development: Training the Trainers," 6th Annual Lilly–East (Atlantic) Conference, Towson, MD, April 2002.

DAWSON, Thomas H., Professor, "Rayleigh Law and Stokes Correction for High Waves in Heavy Seas," Fourth International Symposium on Ocean Wave Measurement and Analysis, San Francisco, CA, 2-6 September 2001.

JOYCE, Peter, Assistant Professor, BARTON, Oscar, Jr., Associate Professor, and MOURING, Sarah E., Associate Professor, "Evaluation of the Effect of Impact Damage on the Mechanical Response of Composite Sandwich Structures," American Society for Composites 16th Annual Technical Conference, Blacksburg, VA, September 2001.

KRIEBEL, David L., Professor, "Air Gap Model Tests on a MOB Module," International Conference On Offshore and Polar Engineering, Stavanger, Norway, June 2001.

KRIEBEL, David L., Professor, "Ocean Engineering Design Experience at the U.S. Naval Academy," Proceedings of the Oceans 2001 Conference, Honolulu, HI, November 2001.

KRIEBEL, David L., Professor, "Wave Amplification and Air Gap Tests on a MOB Module," Proceedings of the 24th US-Japan Marine Facilities Panel, US-Japan Cooperative Program in Natural Resources, Honolulu, HI, November 2001.

KRIEBEL, David L., Professor, "An Overview of Sediment Transport Sections of the New Coastal Engineering Manual," short course sponsored by The American Society of Civil Engineers and presented at Coastal Disasters '02 Conference, San Diego, CA, February 2002.

KRIEBEL, David L., Professor, "U.S. Navigation Channel Design and Practice," U.S. Army Corps of Engineers, Coastal and Hydraulics Lab, Vicksburg, MS, May 2002. (Invited lecturer)

MAYER, Robert H., Associate Professor, and WATERS, Jennifer K., Associate Professor, "Optimal Plans and Costs for Maintenance Dredging Operations," American Society of Civil Engineers (ASCE) Specialty Conference entitled "Dredging '02," Orlando, FL, 7 May 2002.

MAYER, Robert H., Associate Professor, "Development & Success of a Multi-Disciplinary Curriculum in Ocean Environmental Engineering," American Society for Engineering Education (ASEE) 2001 Annual Conference, Albuquerque, NM, 26 June 2001.

MAYER, Robert H., Associate Professor, "Implementing Decision Analysis in Concept Design," American Society for Engineering Education (ASEE) 2001 Annual Conference, Albuquerque, NM, 26 June 2001.

MILLER, Paul H., Assistant Professor, "Finite Element Analysis for Small Craft Structures," International Boat Building Exhibition and Conference (IBEX), Ft. Lauderdale, FL, 8 February 2002.

MILLER, Paul H., Assistant Professor, "Safety Factors in Naval Architecture," Safety-at-Sea Seminar, U.S. Naval Academy, Annapolis, MD, 7 April 2002.

MOURING, Sarah E., Associate Professor, Bigio, D., Schmidt, L., Schmidt, J., Wilkens, G., and Gloster, C., "Enhancing the Student Team Experience in Engineering," BESTEAMS Workshop, Annapolis, MD, May 2002. (SEM: Workshop organizer, presenter and coordinator)

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor, and SIMMONS, D., Kevin, (Trident Scholar, Class of 1999), "External Retrofit of R.C. Beams using CFRP Laminates," Ninth International Conference on Structural Faults and Repair – 2001, London, UK, July 2001.

MOURING, Sarah E., Associate Professor and Reichard, R., "Fabrication of a Composite Superstructure Using a New Assembly Method," International Offshore and Polar Engineering Conference, Stavanger, Norway, June 2001.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor, and SIMMONS, D., Kevin, (Trident Scholar, Class of 1999), "Investigation into the Structural Behavior of Reinforced Concrete Beams Externally Retrofitted with Carbon Fiber Reinforced Polymer Composites," 2001 Second International Conference on Engineering Materials, San Jose, CA, August 2001.

MOURING, Sarah E., Associate Professor, "Behavior of Composite Sandwich Panels Subjected to Impact Damage," National Science Foundation (NSF) Civil and Mechanical Systems Conference, Arlington, VA, October 2001 (Invited speaker)

NUCKOLS, M. L., Professor, "Living Beneath the Sea," Lake Shore Rotary Club in Pasadena, U.S. Naval Academy Speakers Bureau, 17 April 2002. (Invited lecturer)

NUCKOLS, M.L, Professor, "Design of an Oxygen Metabolic Simulator For Use In Unmanned Testing of Underwater Breathing Apparatuses," Underwater Intervention 2002, New Orleans, LA, 1 March 2002. (Invited lecturer)

NUCKOLS, M.L, Professor, "Liquid-Insulation Garments For Long-Duration, Cold Water Diving," Underwater Intervention 2002, New Orleans, LA, 1 March 2002. (Invited lecturer)

NUCKOLS, M.L., Professor, "Comparison of Predicted and Measured Oxygen Levels in a Semi-Closed Underwater Breathing Apparatus," Oceans 2001 Conference, Honolulu, HI, 5-8 November 2001. (Invited lecturer)

NUCKOLS, M.L, Professor, "Design and Evaluation Of A Diver Heater Using Hydrogen Catalytic Reactions," United States-Japan Cooperative Program in Natural Resources (UJNR) Panel on Diving Physiology, Honolulu, HI, 1-3 November 2001 (Invited lecturer)

Schmidt, L., Schmidt, J., Bigio, D., Lent, R., MOURING, Sarah E., Associate Professor, Wilkens, G., and Gloster, C., "Implementing the BESTEAMS Model of Team Development Across the Curriculum," BESTEAMS Workshop I, College Park, MD, August 2001.

Schmidt, J., Bigio, D., and MOURING, Sarah E., Associate Professor, "BESTEAMS Teamwork Training: Facilitating Successful Student Teams," Sixth Annual Conference of the National Collegiate Inventors and Innovators Alliance (NCIIA), Alexandria, VA, March 2002.

Schmidt, L., Schmidt, J., Bigio, D., Lent, R., and MOURING, Sarah E., Associate Professor, "Implementing the BESTEAMS Model of Team Development Across the Curriculum," BESTEAMS Workshop II, College Park, MD, January 2002.

Schmidt, J., Mead, P., Schmidt, L., MOURING, Sarah E., Associate Professor, Wilkens, G., and Gloster, C., "Implementing the BESTEAMS Model of Team Development: Training the Trainers," American Society for Engineering Education (ASEE) Annual Conference & Exposition, Albuquerque, NM, June 2001.

SCHULTZ, Michael P., Assistant Professor, "Three Models to Relate the Detachment of Low Form Fouling at Laboratory and Ship Scale," Office of Naval Research (ONR) Program Review, Baltimore, MD, August 2001.

SCHULTZ, Michael P., Assistant Professor, "The Relationship Between Frictional Resistance and Roughness for Sanded Surfaces," American Physical Society, 54th Annual Meeting of the Division of Fluid Dynamics, San Diego, CA, November 2001.

SMITH, W., Midshipman 1/C (USN), MOURING, Sarah E., Associate Professor, and BURKHARDT, John A., Assistant Professor, "Measurement of Constrained-Layer Damping," EN496 Research Presentation, U.S. Naval Academy, Annapolis, MD, May 2002.

WATERS, Jennifer K., Associate Professor, MAYER, Robert H., Associate Professor, and KRIEBEL, David L., Professor, "Dredging-Related Implications of Current and Future Trends in the International Shipping Industry," Dredging '02, American Society of Civil Engineers, Orlando, FL, 5-8 May 2002.

WATERS, Jennifer K., Associate Professor, (co-presenter), "Channel Design and Vessel Maneuverability - Next Steps," New York Metropolitan Section of the Society of Naval Architects and Marine Engineers, NY, 9 January 2002.

WATERS, Jennifer K., Associate Professor, "Navigation Trends Work Unit: Summary of Findings," Civil Engineering Research Board Meeting, U.S. Army Corps of Engineers, Galveston, TX, 31 July-1 August, 2001.

WATERS, Jennifer K., Associate Professor, "CERB Follow-On: Additional Findings and Discussion of the Navigation Trends Work Unit," U.S. Naval Academy, Annapolis, MD, 20 February 2002.

WATERS, Jennifer K., Associate Professor, and WHITE, Gregory J., Professor, "The Development Of An Archive of Naval Architecture and Ocean Engineering Laboratory Experiments," American Towing Tank Conference, Webb Institute, Glen Cove, NY, 23-24 July 2001.