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 the 2002-2003 Academic Year. As they undertook both sponsored and independent research activities, significant use was made of the Academy's outstanding experimental, computational, and library facilities. The broad spectrum of research themes addressed reflects the varied specialties resident within the department's two areas of technical concentration.

Naval architecture topics included the study and experimental testing of tensile and compressive loads on composite structures - including ultimate strength and failure characteristics. As part of this work, a finite element analysis was first performed on these structures to predict behavior. Research was also conducted on the design and fabrication of a port security barrier system using composite materials. Comparative studies on ship performance prediction methods with respect to tank testing and computational fluid dynamics were completed. The hydrodynamic behavior of a prototype 2200-ton HYSWAS hull form was modeled experimentally in the Hydromechanics Laboratory. In addition, experiments measuring the drag induced by surface roughness, predicting the hydrodynamic performance of sailing yachts, calculating the characteristics of ship generated waves in shallow water, and quantifying the forces produced by moving ships on moored ships were but some of the many research activities conducted by this department's faculty in the Hydromechanics Laboratory.

Ocean engineering topics included studying the hydrodynamic behavior of wave groups, experiments to assist in the development of guidelines for timber wave screens, and tests to compare the performance of antifouling coatings. In materials and structures, research projects addressed the residual strength of blast damaged composite panels, ways to improve composite fabrication, and the mechanical benefits of a concrete like material called ceramicrete. Other research efforts involved the design of passively controlled rebreathers, studies to improve the control of oxygen levels in submarine rescue chambers, ways to enhance the use of renewal ocean energy resources, and surfaced submarine performance while maneuvering in restricted waterways.

Research funds for these and other projects were 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 (NFESC); the U.S. Army Corps of Engineers; the National Science Foundation (NSF); the Naval Surface Warfare Center, Carderock Division (NSWC-CD); the Los Alamos National Laboratory (LANL); the U.S. Coast Guard, the U.S. Department of Energy; the Naval Sea Systems Command (NAVSEA); Team Dennis Connor; and RADM Guy Schaffer, USN, representing the Class of 1951. The faculty and midshipmen of this department appreciate the cooperation and support provided by these sponsoring agencies and organizations.

The department's faculty and midshipmen continue to participate actively in professional meetings and conferences, both nationally and internationally. They had thirteen manuscripts published in professional journals, nineteen articles in conference proceedings, and five technical reports. Thirty-nine presentations were made at numerous 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 have been compared with theoretical work that accounts for nonlinear effects on crest amplitudes. Statistical descriptions of wave groups and wave breaking have been considered. Recent work involved study of high frequency waves and their effects on general statistics of random waves.

Ship Generated Waves

Researchers: Professor David L. Kriebel and Dr. Carolyn Q. Judge (Post-Doctoral Fellow)
Sponsor: Naval Facilities Engineering Service Center (NFESC)

The Naval Facilities Engineering Service Center (NFESC) has initiated an investigation of 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 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 were carried out in the Naval Academy Hydromechanics Laboratory in shallow water conditions where the ship draft is 50 to 90 percent of the water depth. Based on these data, coupled with data obtained from the literature, a new empirical method of predicting ship squat, trim, and ship-generated waves was developed. The key element of this approach is a modified definition of the Froude number that incorporates the water depth and ship draft.

Shoreline Management Task Force of U.S.-Canada International Joint Commission on Great Lakes

Researchers: Professor David L. Kriebel and Dr. Carolyn Q. Judge (Post-Doctoral Fellow)
Sponsor: U.S. Army Corps of Engineers, Buffalo, NY District

Professor Kriebel was appointed by U.S. Army Corps of Engineers as one of two U.S. representatives to oversee research activities pertaining to joint U.S.-Canadian management of the Lake Ontario shorelines. The U.S.-Canada International Joint Commission on the Great Lakes regulates water levels in the Great Lakes to aid commercial navigation and hydropower production. Proposals to increase lake levels in Lake Ontario would have adverse impacts on shoreline erosion for the Ontario and New York shorelines. Several consulting firms are undertaking a three-year study of these erosion impacts. A Shoreline Management Task Force, consisting of two U.S. representatives and two Canadian representatives is then overseeing and reviewing the work of the consultants.

Mooring Forces Induced by Passing Ships

Researchers: Professor David L. Kriebel and Louise A. Wallendorf, P.E., (Hydromechanics Laboratory)
Sponsor: Naval Facilities Engineering Service Center (NFESC)

The Navy has recently been experiencing damage to moored ships and piers as a result of excessive motions of the moored vessel caused by passing ship traffic. Many Navy piers are located alongside commercial navigation channels where commercial vessels enter/exit port at a high rate of speed. The waves generated by these vessels may then induce large surge, sway, or yaw motions of any vessels moored at the pier. In order to better understand this problem, a series of physical model tests are being conducted in the Hydromechanics Laboratory. In these tests, one ship model is moored using load cells while another ship model is towed past at various speeds and separation distances. Data analysis is underway to develop empirical guidelines on the surge force, sway forces, and yaw moments experienced acting on the moored vessel. The results will also be used to validate computer codes used by the Naval Facilities Engineering Service Center.

Development of Design Guidelines for Timber Wave Screens

Researcher: Professor David L. Kriebel
Sponsor: U.S. Coast Guard Civil Engineering Unit, Providence

The U.S. Coast Guard maintains numerous boat launches, piers, and floating docks that are used by small search-and-rescue vessels. A common problem is the lack of protection from wave attack. In many cases, the facilities are small and large breakwaters are not economically feasible. As a result, wave protection is provided by small low-cost vertical timber wave screens, also called wave barriers or wave fences. Research efforts at the Naval Academy include: (1) selected physical model tests on typical wave screens configurations, (2) development of a predictive model to assess wave transmission past wave screens and wave forces on wave screens, and (3) development of general design guidelines to be used by the Coast Guard in future repair or new construction of timber wave screens.

Renewable Energy Options for American Samoa

Researcher: Professor Robert H. Mayer
Sponsor: U.S. Department of Energy (DoE)

Is it wise for American Samoa to depend on diesel fuel to produce all of its electricity? Or is it wiser to produce its electricity using the sun, wind, heat from the island, or energy from the ocean? Clearly the resource options are abundant, but what are the costs? Can the American Samoa Government afford it? Can it afford NOT to? These were some of the questions addressed in a two-day workshop held in Pago Pago, Territory of American Samoa, in November 2002. The goal of the workshop was to identify and assess renewable energy options that may be feasible for the Territory. Leaders in their respective fields were carefully selected to provide the most up-to-date information possible. The principal investigator from the U.S. Naval Academy was invited to present the state-of-the-art in ocean energy conversion. Other investigators spoke on wind, geothermal, solar and bio-energy conversion technologies. A panel discussion followed the presentations, including question and answer sessions.

Composite Materials Research for Team Dennis Conner

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

Project included research, analysis, testing and design of composite material components for two 78-foot racing vessels used in the 2003 America's Cup competition. Specific tasks included: a) Finite element analysis (FEA) (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 SATEC machine in Rickover Hall during June and July. 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. e) Quality Assurance/Quality Control specifications and process implementation for builders. f) Forensic analysis of damaged parts. The project also included recommendations for repair and prevention.

Composite Port Security Barrier Feasibility Study

Researcher: Assistant Professor Paul H. Miller
Sponsor: Naval Facilities Engineering Service Center (NFESC)

To provide protection from small craft attack, the Navy has deployed static port security barriers (PSB) at major naval bases. The design consists of a series of mild steel floating units, each of which has three pontoons joined by a backbone structure. Although coated with a corrosion-resistant barrier paint, initial units have shown premature corrosion leading to higher-than-desired maintenance requirements. Potential solutions to this problem include improved surface preparation, material substitution or the use of a different paint system. Alternate materials include marine grade aluminum, stainless steel and composite materials. This study looked at the feasibility of composite materials for the pontoons. Composite materials used in similar marine applications were the basis for this study and preliminary structural analyses using the finite element method was performed. The design criteria for the composite PSB were identical to the current PSB. Although the

goal was to identify a solution that resulted in lower weight and life-cycle costs, initial costs were deemed important. Five composite materials were chosen for final study. Two were thermoplastics commonly used in dock pontoons. The three others were polyester and vinyl ester/E-glass laminates; two consisting of chopped strand mat and the other of a mixture of mat and woven roving. Although all five appear technically feasible and meet all the design criteria, the vinyl ester and chopped strand mat pontoon was selected based on cost and other factors.

Residual Strength and Stiffness of Blast Damaged Composite Panels

Researcher: Associate Professor Sarah E. Mouring
Sponsor: Office of Naval Research (ONR)

Conventional fiberglass composite construction has dominated the recreational boating industry for the past four decades. The U.S. Navy, however, has not been as quick to embrace composite materials as alternatives to traditional materials such as steel and aluminum. Recently, there have been major improvements in composite fabrication (resin infusion and pre-impregnated reinforcements mainly) plus an increased demand for reduced electronic signatures for naval applications. Due to these improvements and the need for fast, light-weight naval ships, composite materials are being chosen more frequently for naval applications. This trend is evident in the incorporation of composite materials in new secondary ship structures and replacement of metallic components with composite ones. However, there is a lack of confidence when designing primary structures using composite materials compared to traditional materials. The acceptance and future growth of composite construction partially depends on the ability of the designer to predict accurately the hull performance of a ship subjected to different loading conditions. Understanding the performance of composite materials and their failure (damage / ruptures), when subjected to explosion, is essential for their use in hull construction. However, there has been very little work on the determination of ultimate or residual strength of composite structures after an explosion. At this time, ultimate strength can be predicted for steel structures with different damage conditions using the DoN ULTSTR software program. This program has not been used to predict ultimate strength of composite structures. Part of this proposed study would include the incorporation of composite material properties and damage models into the ULTSTR ultimate strength program which currently only deals with steel ships. However, in order to establish a simple model using composite materials, we need to use a more complex model, such as explicit finite element analyses, which has to be validated against large scale tests. This is required in order to ensure that the various failure patterns can be correctly modeled and the parameters which influence the behavior are fully understood. This would provide the necessary confidence in developing a simpler model into the existing Navy program, ULTSTR.

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 proposes to develop a four-year, team training curriculum model that can be integrated into any existing engineering curriculum. Full development of the model includes 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, including the Naval Academy.

Passively Controlled Semi-Closed/Closed Rebreather Development

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

This is the fourth year of a 5-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.

Tech Solution #TS-000108: Closed Circuit Rebreather

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

The objective of this one-year effort is to apply lessons learned during previous ONR-sponsored research in rebreather technology to design, fabricate and test a rebreather circuit capable of being manually switched between closed circuit mode using pure oxygen and semi-closed circuit operations. For instance, a combat swimmer can use this rebreather in a closed circuit mode with pure oxygen when a shallow, covert operation is called for, and then switch to semi-closed mode during a transit phase in which he may be at depths in excess of exposures that pure oxygen could be tolerated (oxygen partial pressures above 1.6 atmospheres). To switch from semi-closed to closed modes during the mission, the diver only needs to ascend to a depth where breathing pure oxygen can be tolerated (less than 25 feet of seawater), purge the circuit with oxygen and then activate a change-over switch to de-couple a sonic injection of fresh makeup gas. The diver can then swim covertly in the closed-circuit mode without dumping circuit exhaust into the seawater. When it is necessary to descend to a deeper depth, during submarine entry for instance, the diver can purge the circuit again with an oxygen-rich nitrox mixture and then re-activate sonic injection of the makeup gas. The most direct solution, first proposed in the original project proposal, involves a modification of a closed-circuit, pure oxygen rebreather, such as the MK25 (LAR V) or equivalent, to allow it to be switchable to semi-closed during excursions beyond 20 FSW.

Development of an Oxygen "Metabolizer" to Control Oxygen Levels in the Closed Cabins of Rescue Vehicles

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

This was the second year of a two year effort funded by Naval Sea Systems Command to investigate methods to reduce oxygen levels inside submarine rescue chambers. This effort resulted as a spinoff from the successful diver heater technology funded in past years by Office of Naval Research. It uses the same hydrogen catalytic processes to consume oxygen at elevated pressures as have been successfully used previously to produce heat.

Naval Forces Under the Sea: The Rest of the Story

Researchers: Professor Marshall L. Nuckols and Donald Chandler
Sponsor: Office of Naval Research (ONR)

This is the first year of a two year effort under funding from the Office of Naval Research to document the history of diving in a book to be titled Naval Forces Under the Sea: The Rest of the Story. Icons in the diving discipline are being interviewed during FY03 in this joint effort with the Undersea and Hyperbaric Medical Society prior to the publication of the book in FY04.

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 proposed 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.

National Naval Program for Naval Engineering

Researchers: Associate Professor Jennifer K. Waters
and Professor Robert H. Mayer (Naval Architecture and Ocean Engineering)
and Associate Professor Bradley E. Bishop
and Assistant Professor Jenelle A. Piepmeier (Weapons and Systems Engineering Department)
Sponsor: Office of Naval Research (ONR)

The U.S. Naval Academy, the Stevens Institute of Technology and the University College of London are partners in the Atlantic Center for the Innovative Design and Control of Small Ships. The partners appreciate the ONR concern that there is a deteriorating critical mass surrounding classical design centers for Naval Architecture and Marine Engineering in the United States. Unless this critical mass is regenerated, it is inevitable that U.S. Naval ships will eventually lag in both innovation and technical development. A major challenge in U.S. Navy ship design in the 21st Century is ensuring performance and affordability with a reduced crew size while also maintaining high reliability and damage control. This challenge is particularly evident in the design of vessels to meet the Navy's new and emerging needs in the littoral zone. These needs require fast, relatively small vessels capable of operating in the range of weather and ocean conditions encountered in the littoral environment while also meeting the Navy's payload requirements. The Atlantic Center proposes to address this issue by focusing on two key areas. First is in establishing an environment where engineering disciplines associated with hull design and ship automation can be brought together within the context of the total ship system architecture. Second is the utilization of this unique education and research environment in the recruiting, training and long-term career development of the best and brightest young engineers in the U.S. By capitalizing on its partnership, the Atlantic Center will provide the creative, inter-disciplinary environment in which to educate the next generation of Naval Engineers, and will open the door to exciting long-term career opportunities for graduates of the program. In this fashion, the Atlantic Center will foster and instill innovation and creativity into the future leadership of the U.S. Navy, and will ensure the nation's ability to maintain superior naval forces.

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 aims to calibrate and validate a numerical hydrodynamic computer model with existing physical experimental model test data. The numerical model will then be 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 by Associate Professor Waters for the U.S. Army Corps of Engineers on Deep-Draft Navigation Channel Design. The new work investigates 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 investigates, quantifies and develops an approach for controlling or managing these forces through navigation channel design and/or waterway management.

The Atlantic Center for the Innovative Design and Control of Small Ships

Researcher: Associate Professor Jennifer K. Waters
Sponsor: Office of Naval Research (ONR)

The Atlantic Center for the Innovative Design and Control of Small Ships is comprised of representatives from three academic institutions (the United States Naval Academy, the Stevens Institute of Technology and University College of London) and two major industry partners (M. Rosenblatt & Son, an AMSEC LLC Group, and Lockheed-Martin Corporation). There have been significant improvements in the process design function in today's shipbuilding industry. There has however been little focus on integrating, perhaps through radical design changes, all the engineering disciplines associated with shipbuilding. A major challenge in U.S. Navy ship design in the 21st Century is ensuring performance and affordability with a reduced crew size while also maintaining high reliability and damage control. This challenge is particularly evident in the design of vessels to meet the Navy's new and emerging needs in the littoral zone. These needs require fast, relatively small vessels capable of operating in the range of weather and ocean conditions encountered in the littoral environment while also meeting the Navy's payload requirements. The Atlantic Center for the Innovative Design and Control of Small Ships is addressing this issue by focusing on two key areas. First is in establishing an environment where engineering disciplines associated with hull design and ship automation can be brought together within the context of the total ship system architecture, thereby facilitating the creative knowledge development, educational changes and discipline integration required for true innovation. Second is the utilization of this unique education and research environment in the recruiting, training and long-term career development of the best and brightest young engineers in the U.S.

Resistance, Seakeeping, and Wake Survey Testing of the 2200 LT MCM(XH) HYSWAS Hull Form

Researcher: Professor Gregory J. White
Sponsor: Office of Naval Intelligence (ONI)

Maryland Applied Physics Corporation (MAPC) has developed a unique hull-form for a new mine counter-measures ship with a very high-speed capability. This hull form is a modified version of the one tested by the Naval Academy's Hydrodynamics Laboratory (NAHL) in May of 2001. The modifications allow the ship to operate in shallower waters while still retaining the high speed capability. The modifications include a decrease of the hullborne draft, reshaping the underwater hull, and a redesign of the underside of the cross-deck structure.

Three model test series have been performed to provide MAPC with foilborne powering and wake information, and wave loading information when foilborne at high speeds. This information will facilitate the design of the propeller for the ship and provide some information to help evaluate the foilborne seakeeping performance of the ship. For the Effective Horsepower (EHP) Test and Wave Loading Test the model was configured without foils. The foil resistance was calculated separately and added to the measured resistance. During the Wake Survey the foils were attached to the model to insure that the flow field in the vicinity of the propeller location was correctly scaled. For all of the tests the model was held rigidly in place at the desired draft and trim, and measurements were recorded for vertical force, drag force, and encounter wave amplitude. The model draft corresponded to a full-load condition of 1,400 LT (foilborne). The model trim varied between 0° and 3° (bow up) as prescribed in the test plan.

Independent Research

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 papers: "Similitude in the Cardiovascular System of Mammals," (*Journal of Experimental Biology*, Vol. 204, pp. 395-407, February 2001); and "Scaling Laws for the Capillary Vessels of Mammals at Rest and in Exercise" (*Proceedings of the Royal Society London*, Vol. 270, pp. 755-763, April 2003).

Tank Testing of Luders 44 Navy Yawl

Researcher: Assistant Professor Paul H. Miller

Tank testing of the Ludders 44 yawl model in upright and heeled conditions was accomplished to support a paper for the Chesapeake Sailing Yacht Symposium. The Ludders yawl was the primary Navy sail-training vessel up until the late 1970's time frame. The performance of this yawl provides a basis of comparison for the more modern design that is now in service as well as next generation craft, which is currently in its final design stage.

Midshipman Research Course Projects

Bridging the Gaps: Finding Solutions for the Florida Overseas Heritage Trail at the Seven Mile Bridge

Researchers: Midshipman 1/C Victoria L. Burns, USN and Midshipman 1/C John A. Pegues, USN
Advisers: Professor David L. Kriebel and Professor Robert H. Mayer

In this project, various design alternatives for extending the Florida Heritage Overseas Trail (FOHT) over several gaps that exist in the old Seven Mile Bridge in the Florida Keys were considered. The FOHT is part of the East Coast Greenway, a planned pedestrian and bicycle trail extending from Maine to Key West. The FOHT makes use of many of the old abandoned U.S. Route 1 highway bridges that exist in the Florida Keys; however, several sections of these bridges were demolished and gaps now exist in these locations. The researchers made a site visit to the Keys, met with local officials from the FOHT (part of the Florida State Park system), and then developed design options for "bridging the gaps." Midshipman Burns focused on "passive" options, *i.e.,* bridges that did not require human operators. After considering numerous design options, she identified a box-ramp system as the best bridge alternative. Midshipman Pegues evaluated "active" options that would require hiring a permanent staff. After considering shuttle vans, buses, and ferry systems, he identified the shuttle van as the best option. The two main options were then presented to the Florida State Park officials for further consideration.

A Hydrodynamic Study of Fish Haven Breakwaters

Researcher: Midshipman 1/C Brendan R. Gotowka, USN
Advisers: Professor Robert H. Mayer and Associate Professor Jennifer K. Waters

Fish Havens are a modular artificial reef system designed, fabricated, and installed by Artificial Reefs Inc. (ARI) of Gulf Breeze, FL. Individual units are formed of concrete in the shape of a truncated pyramid, ranging in size from 4'-6' tall, and 8'-10' wide at the base. Traditionally, Fish Havens have been used successfully as a synthetic replacement for damaged corals as well as for creating new reef habitats in desolate ocean environments. ARI also proposes using their

Fish Havens in a shoreline protection role. This study seeks to assess how effective this modular system would be in such a deployment.

Using 6" x 10" Fish Haven models provided by ARI, two different configurations of a Fish Haven breakwater were arranged in the sediment flume of the U.S. Naval Academy's Hydromechanics Laboratory. Different Bretschneider-spectrum wave series were propagated and changes in sediment bathymetry were compared with a no-breakwater (NBW) condition. Both Fish Haven configurations induced formation of a prominent sand berm of shallower depth and closer to shore than the NBW condition. Shoreline retreat was also reduced 33%.

A second means to assess Fish Haven effectiveness was to measure the amount of wave energy dissipated by the breakwater system. Series of steady waves of different frequencies were generated and wave height measurements were taken both before and after passing over the breakwater. Wave heights were then correlated with wave energy and compared with similar calculations made for the NBW condition. Results were inconclusive in part due to effects of wave reflection off the shoreline. Also, wave energy dissipation - in shallow water - is not proportional to changes in wave height (as originally assumed.) Future studies of wave energy dissipation should consider comparison of changes in wave energy flux which is a function of both wave height and depth.

The Re-Invention of the *Turtle*'s Propeller

Researcher: Midshipman 1/C David Yoon, USN
Adviser: Assistant Professor Paul H. Miller

The U.S. Naval Academy, the Massachusetts College of Arts (MCOA), and the Discovery Channel combined efforts to re-invent David Bushnell's submersible, the *Turtle*. One area of particular concern was the craft's propeller for horizontal movement. This project's goal was to design the best possible propeller in order to maximize the performance and speed of the submersible. The propeller design was to take into account historical references, the best possible technology available at the time of the Revolutionary War, as well as those materials that it would likely be constructed from. Using modern propeller and propulsion theory, lift, drag, and resistance were all evaluated in the design process. Finally, the feasibility of SGT Ezra Lee actually conducting an attack with the *Turtle* on the British fleet in New York Harbor could be determined by the speeds determined possible, and the historical time constraints with which he was allotted. The final propeller design was compared to the one produced by MCOA and was found to be roughly three times more efficient. This meant that the maximum possible speed from the full-scale Turtle interpretive replica would be roughly 1.3 mph.

Mechanical Behavior of Ceramicrete

Researcher: Midshipman 1/C Victoria L. Burns, USN
Advisers: Associate Professor Sarah E. Mouring and Assistant Professor Paul H. Miller
Sponsor: Los Alamos National Laboratory (LANL)

Ceramicrete is a relatively new engineering development that uses an acid-base reaction between magnesium oxide (MgO; a base) and a solution of potassium hydrogen phosphate (KH_2PO_4; an acid). The product of this reaction is the binder that can be used as a matrix material in forming a concrete-like material. This material is light weight, fast-drying, and has a high strength. Currently, ceramicrete is being studied as a material used to stabilize radioactive wastes by the Department of Energy. Because of the considerable properties of this material, ceramicrete shows potential for being used in nearly all applications requiring concrete. Experimental testing was performed in this study to examine the properties of ceramicrete. Three objectives, in particular, were studied: 1) to question whether or not ceramicrete chemically bonds to itself, 2) to question whether or not ceramicrete is weaker at the bond if there is no chemical bond, and 3) to examine the possibility of a chemical bond between ceramicrete and clean or dirty portland cement-based concretes. If ceramicrete were favorable in all three areas, this new concrete-like substance could be of great benefit to the military. This concrete-like material could be used for combat engineering purposes where they currently use concrete. Additionally, it could be used for runway or roadway repair, existing dockside repair, or a replacement material for the grout plugs used by the department of energy in weapons testing. To accomplish the objectives, two tests were performed. They were a compression test and a short beam flexure test. Overall, ceramicrete appears to be a breakthrough in concrete technology. Further testing is needed before ceramicrete will become common material used by contractors. There does not appear to be any chemical

bonding occurring when ceramicrete is poured although ceramicrete definitely has a better mechanical bond than any known concrete. Ceramicrete is decidedly a material with great potential and possibility for its usage.

Evaluation of Composites Fabricated using SCRIMP

Researcher: Midshipman 1/C David J. Walter, USN
Adviser: Associate Professor Sarah E. Mouring
Sponsor: Office of Naval Research (ONR)

The Seeman Composite Resin Infusion Molding Process, known as SCRIMP, is a relatively new method to produce composite parts. SCRIMP is a specialized technique of the Vacuum Assisted Resin Transfer Molding (VARTM) methods which uses the pressure differential from a vacuum system to infuse the fabric mat with resin. It is designed to keep the void content low as well as increase the fiber-to-resin ratio. While these advantages can help the designer by increasing the yield of the material, it is a more complicated process and therefore can produce weaker parts if not controlled properly. Methods are needed to guarantee the quality of panels produced using SCRIMP. This project addresses the fabrication process as well as different methods used for quality control. These methods include ultrasonic transmission, high power magnification, and the short beam shear test.

Comparison of Three Roughness Function Determination Methods

Researcher: Midshipman 1/C Alexandra Meyers, USN
Adviser: Assistant Professor Michael P. Schultz

Three methods have been used to experimentally determine the roughness function (ΔU^+) for several rough surfaces. These include the rotating disk, the towed plate, and the velocity profile methods. The first two are indirect methods in as much as they rely on measurements of overall torque or resistance and boundary layer similarity laws to obtain ΔU^+, whereas the velocity profile method provides a direct measurement of ΔU^+. The present results indicate good agreement between the towed plate and the velocity profile methods for all of the surfaces tested. Tests for the rotating disk were carried out at much higher unit Reynolds numbers. Using this method, the results for sandpaper rough surfaces agree within their uncertainty with a Nikuradse-type roughness function in the fully-rough regime, while a spray painted surface agrees with a Colebrook-type roughness function.

HMS Inconstant: Preparation for Model Testing

Researcher: Midshipman 1/C James A. Wolff, USN
Adviser: Professor Gregory J. White
Sponsor: U.S. Naval Academy Class of 1951

This research project was a small part of a long term effort to perform hydrodynamic performance analysis on selected ships from the Naval Academy Museum's historic model collection. The specific purpose of this project was to develop a methodology for lifting the lines from a historic ship model and to prepare a three-dimensional computer model which will be used to manufacture a new model. The new model was built to a suitable scale and constructed to facilitate testing in the NAHL 380' towing tank. The historic ship models are delicate specimens of significant historic interest which must not be damaged in the process. The primary challenge in this project was to create a methodology for lifting the model lines with enough information to allow for the construction of the computer model. A second challenge was to establish a process for using the information from the historic model to insure that the computer model accurately represents the historic model. The specific goal of this project was to document the processes developed and to have everything ready to begin construction of a new fiberglass and foam model.

The model chosen for this effort was the *HMS Inconstant* (model # 52 in the museum collection). The original ship was a 38-gun, 18-pounder 5th Rate British frigate built in 1783. As a long term project, a secondary goal was set to provide for a basis of comparison with past and future projects of a similar nature. This goal was to investigate any pertinent historical information such innovations of the time period or any particular data on the *Inconstant*. This model is also special because the superstructure has collapsed and therefore is just a bare hull. In being so it is the perfect model to test in the new measuring apparatus in the model shop.

Trident Scholar Project

Ship Performance Prediction Methods with Respect to Tank Testing and Computational Fluid Dynamics (Trident Report # 315)

Researcher: Midshipman 1/C Jon P. Silverberg, USN
Adviser: Assistant Professor Paul H. Miller
Sponsor: Office of Naval Research (ONR)

The goal of this Trident Scholar project was to compare tank testing and computational fluid dynamics in their uses to naval architecture. The traditional process of ship performance prediction is hydrodynamic tank testing where a scale model of the ship is towed to measure the forces scalable to full size. Each trial includes different conditions such as speed, rudder angle, yaw angle, or heel angle. The results can then be scaled up for the actual ship. However, proposed design changes are expensive and time-consuming to analyze, as they require new models.

Since the advent of the computer, the use of Computational Fluid Dynamics (CFD) is available for ship performance prediction. CFD uses a digitized ship hull placed onto water panels of a virtual sea and calculates the water pressure on each part of the hull. This provides lift and drag predictions. In CFD, there is no problem with modeling similarity. Design changes are relatively easy and inexpensive to evaluate, but large computing resource requirements force numerical simplifications in the code. Nonetheless, CFD is approaching the accuracy of the tank.

The project compared ship performance prediction methods using a simple PC-based CFD code (FKS) developed by engineers at the Naval Surface Warfare Center, Carderock, versus a complex mainframe code from Patuxent River Naval Air Station (SPLASH). These results were compared to tank test data developed in the Naval Academy's Hydrodynamics Laboratory. The Mk II Navy 44 Sail Training Craft served as the baseline design due to its design complexity and intended future service with the Naval Academy. Differences in each set of results were explored in areas such as lifting surfaces, leeway, free surface effects, and turbulence. To test the use of CFD as a design tool, a rudder design matrix was developed. This project proved that CFD is a valuable and accurate tool for naval architecture in the design of ships. Furthermore, after developing a velocity prediction program, a prediction of the sailing characteristics of the vessel was calculated, allowing for design improvements, which potentially benefit the Command Seamanship and Navigation Training Squadron and Varsity Offshore Sailing Team.

Publications

Journal (Refereed) Manuscripts

DAWSON, Thomas H., Professor, "Scaling Laws for Capillary Vessels of Mammals at Rest and in Exercise," *Proceedings of the Royal Society,* Vol. 270, 2003, pp. 755-763.

A general derivation is presented for the scaling laws governing the size and number of the capillary blood vessels in mammals. The derivation is based on the assumption of three idealized similarity principles known to apply, *at least approximately*, to resting mammals: size invariant blood pressure, size invariant fraction of blood in the capillaries, and size invariant oxygen consumption and uptake, per unit of body mass, during each heart cycle. Results indicate that the radius and length of capillaries and the number that are open and active in the resting state should scale with mammal mass to the powers 1/12, 5/24, and 5/8, respectively, consistent with earlier work by the writer. Measurements are presented supporting the results. Physiological changes accompanying strenuous exercise are accounted for by change in the scaling law for capillary number, from scaling exponent 5/8 to 3/4.

Gray, William O., WATERS, Jennifer K., Associate Professor, Blume, Alan L., and Landsburg, Alexander, "Channel Design and Vessel Maneuverability: Next Steps," *Marine Technology*, Vol. 40, No. 2, 2003, pp.93-105.

A recent workshop on channel design and vessel maneuverability brought together channel designers, naval archi-

tects, pilots, and ship operators to review and share design approaches and standards that affect safety of operations. The desire was to develop policy recommendations that can be implemented both in the way channels are laid out and enlarged and how ships of various types using them should be designed and handled. Resulting recommendations based on the discussions promise to improve overall safety of ship operations in restricted waterways.

MIKLOSOVIC, David S., Assistant Professor (Aerospace Engineering Department), SCHULTZ, Michael P., Assistant Professor, and ESQUIVEL, Christian, Midshipman 1/C, USN, "Effects of Surface Finish on the Aerodynamic Performance of a Representative Stabilizer," *Journal of Aircraft*, accepted.

A sailboat centerboard, representative of a vertical stabilizer, was wind tunnel tested at different surface finish conditions to ascertain the effects on performance. The stabilizer model had a NACA 0009 airfoil section, an aspect ratio of 1.8, and a leading edge sweep angle of 22°. Tests were run at Reynolds numbers of $5x10^5$ and $1x10^6$, based on the mean aerodynamic chord. Surface finishes of 0.04-0.46 mils (1.0-11.6μm) RMS roughness height were generated by sanding with different grit abrasives and quantified using laser scanning techniques. The effects of the rougher surface finishes were to increase the maximum lift coefficient (20%), decrease the drag coefficient at maximum lift (51%) and increase the pitching moment coefficient (25%). The combination of the roughest surface finishes at the higher Reynolds number delayed flow separation to higher angles of attack and qualitatively changed the stall characteristics, resulting in the greatest improvements over the "smooth" surface conditions. These results indicate that polishing does not necessarily improve the performance of stabilizers, but the range of effect is outside the typical operating envelope of such control surfaces.

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. 36, No. 9, 2002, pp. 1065-1078.

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.

Roberts, J.C., Boyle, M.P., Weinhold, P.D., Ward, E.E., and WHITE, Gregory J., Professor, "Strains and Deflections of GFRP Sandwich Panels Due to Uniform Out-of-Plane Pressure," *Marine Technology*, Society of Naval Architects and Marine Engineers (SNAME), Vol. 39, No. 4, 2002, pp. 223-231.

Rectangular orthotropic glass fiber reinforced sandwich panels were tested under uniform out-of-plane pressure and the strains and deflections were compared with those from finite element models of the panels. The panels, with 0.32 cm (0.125 in.) face sheets and 1.27 cm (0.5 in.) core of either balsa or linear polyvinylchloride foam, were tested in two sizes: 183 x 92 cm (72 x 36 in.) and 121 x 92 cm (38 x 36 in.). The sandwich panels were fabricated using the vacuum-assisted resin transfer molding technique. The two short edges of the panels were clamped, while the two long edges were simply supported. Uniform external pressure was applied using two large water inflatable bladders in series. The deflections and strains were measured using dial gages and strain gages placed at the quarter and half points on the surface of the panels. Measurements were made up to a maximum out-of-plane pressure of 0.1 Mpa (15 psi). A total of 6 balsa core and 6 foam core panels were tested. Correlation between numerical and experimental strains to deflect the panel was much better on the top (tensile) side of the panels than the bottom (compressive) side of the panels, regardless of panel aspect ratio or core material.

SCHULTZ, Michael P., Assistant Professor, and FLACK, Karen A., Associate Professor (Mechanical Engineering Department), "Turbulent Boundary Layers over Surfaces Smoothed by Sanding," *Transactions of the American Society of Mechanical Engineering (ASME) Journal of Fluids Engineering*, Vol. 125, 2003, pp. 863-870.

Flat plate turbulent boundary layer measurements have been made on painted surfaces, smoothed by sanding.

The measurements were conducted in a closed return water tunnel, over a momentum thickness Reynolds number (Re_θ) range of 3,000 to 16,000, using a two-component, laser Doppler velocimeter (LDV). The mean velocity and Reynolds stress profiles are compared with those for smooth and sandgrain, rough walls. The results indicate an increase in the boundary layer thickness (δ) and the integral length scales for the unsanded, painted surface compared to a smooth wall. More significant increases in these parameters, as well as the skin-friction coefficient (C_f) were observed for the sandgrain surfaces. The sanded surfaces behave similarly to the smooth wall for these boundary layer parameters. The roughness functions (ΔU^+) for the sanded surfaces measured in this study agree within their uncertainty with previous results obtained using towing tank tests and similarity law analysis. The present results indicate that the mean profiles for all of the surfaces collapse well in velocity defect form. The Reynolds stresses also show good collapse in the overlap and outer regions of the boundary layer when normalized with the wall shear stress.

SCHULTZ, Michael P., Assistant Professor, and MEYERS, Alexandra, Midshipman 1/C, (USN), "Comparison of Three Roughness Function Determination Methods," *Experiments in Fluids*, 2003, pp. 372-379.

Three methods have been used to experimentally determine the roughness function (ΔU^+) for several rough surfaces. These include the rotating disk, the towed plate, and the velocity profile methods. The first two are indirect methods in as much as they rely on measurements of overall torque or resistance and boundary layer similarity laws to obtain ΔU^+, whereas the velocity profile method provides a direct measurement of ΔU^+. The present results indicate good agreement between the towed plate and the velocity profile methods for all of the surfaces tested. Tests for the rotating disk were carried out at much higher unit Reynolds numbers. Using this method, the results for sandpaper rough surfaces agree within their uncertainty with a Nikuradse-type roughness function in the fully-rough regime, while a spray painted surface agrees with a Colebrook-type roughness function.

SCHULTZ, Michael P., Assistant Professor, and VOLINO, Ralph J., Assistant Professor (Mechanical Engineering Department), "Effects of Concave Curvature on Boundary Layer Transition under High Free-Stream Turbulence Conditions," *Transactions of the American Society of Mechanical Engineering (ASME) Journal of Fluids Engineering*, Vol. 125, 2003, pp. 18-27.

An experimental investigation has been carried out on a transitional boundary layer subject to high (initially 9%) free-stream turbulence, strong acceleration ($K = (\nu / U_w^2)(dU_w / dx)$ as high as 9×10^{-6}), and strong concave curvature (boundary layer thickness between 2% and 5% of the wall radius of curvature). Mean and fluctuating velocity as well as turbulent shear stress are documented and compared to results from equivalent cases on a flat wall and a wall with milder concave curvature. The data show that curvature does have a significant effect, moving the transition location upstream, increasing turbulent transport, and causing skin friction to rise by as much as 40%. Conditional sampling results are presented which show that the curvature effect is present in both the turbulent and non-turbulent zones of the transitional flow.

Stein, J., Truby, K., Darkangelo-Wood, C., Takemori, M., Vallance, M., Swain, G., Kavanagh, C., Kovach, B., SCHULTZ, Michael P., Assistant Professor, Wiebe, D., Holm, E., Montemarano, J., Wendt, D., Smith, C., and Meyer, A., "Structure-Property Relationships of Silicone Biofouling-Release Coatings: Effects of Silicone Network Architecture on Pseudobarnacle Attachment Strengths," *Biofouling*, Vol. 19, 2003, pp. 87-94.

Model silicone foul-release coatings with controlled molecular architecture were evaluated to determine the effect of compositional variables such as filler loading and crosslink density on pseudobarnacle attachment strength. Pseudobarnacle adhesion values correlated with filler loadings in both condensation and hydrosilylation-cured silicones. Variation of crosslink density of hydrosilylation-cured silicones had an insignificant effect on attachment strength. X-ray photoelectron spectroscopy (XPS) indicated that the mode of failure was dependent upon crosslink density; samples with high crosslink density failed cohesively within the silicone.

Stein, J., Truby, K., Darkangelo-Wood, C., Stein, J., Gardner, M., Swain, G., Kavanagh, C., Kovach, B., SCHULTZ, Michael P., Assistant Professor, Wiebe, D., Holm, E., Montemarano, J., Wendt, D., Smith, C., and Meyer, A., "Silicone Foul Release Coatings: Effect of the Interaction of Oil and Coating Functionalities on the Magnitude of Macrofouing Attachment,"

Biofouling, Vol. 19 (supplement), 2003, pp. 71-82.

Silicone biofouling release coatings have been shown to be an effective method of combating fouling. Nearly all silicone foul release coatings are augmented with an oil additive to decrease macrofouling attachment strength. This paper addresses the effect of the type of oil that is incorporated into the silicone coating and the type of silicone itself (silica vs. calcium carbonate filled) on macrofouling adhesion strengths to the coating. It was found that not only are the main effects of oil type and silicone coating type important in determining the magnitude of the attachment strength of the organism, but the interaction term (oil type crossed with coating type) is highly significant for all organisms studied, except oysters at the University of Hawaii test site (Oahu, Hawaii), which has a significance level of $\alpha = 0.1$. Each of the organisms exhibited a unique response to the various silicone fouling release coatings. Thus, in order to predict the effectiveness of foul release coatings, the composition variables of the coatings and the type of target organism must be considered.

VOLINO, Ralph J., Associate Professor (Mechanical Engineering Department), SCHULTZ, Michael P., Assistant Professor, and PRATT, Christopher M., Midshipman 1/C, USN, "Conditional Sampling in a Transitional Boundary Layer under High Free-Stream Turbulence Conditions," *Transactions of the American Society of Mechanical Engineering (ASME) Journal of Fluids Engineering*, Vol. 125, 2003, pp. 28-37.

Conditional sampling has been performed on data from a transitional boundary layer subject to high (initially 9%) free-stream turbulence and strong ($K = (\nu / U_\infty^2)(dU_\infty / dx)$ as high as 9×10^{-6}) acceleration. Methods for separating the turbulent and non-turbulent zone data based on the instantaneous streamwise velocity and the turbulent shear stress were tested and found to agree. Mean velocity profiles were clearly different in the turbulent and non-turbulent zones, and skin friction coefficients were as much as 70% higher in the turbulent zone. The streamwise fluctuating velocity, in contrast, was only about 10% higher in the turbulent zone. Turbulent shear stress differed by an order of magnitude, and eddy viscosity was three to four times higher in the turbulent zone. Eddy transport in the non-turbulent zone was still significant, however, and the non-turbulent zone did not behave like a laminar boundary layer. Within each of the two zones there was considerable self-similarity from the beginning to the end of transition. This may prove useful for future modeling efforts.

Conference Proceedings

BARTON, Oscar, Jr., Associate Professor (Mechanical Engineering Department), and MILLER, Paul H., Assistant Professor, "Composite Structural Mechanics at the United States Naval Academy," *Proceedings of the 2003 American Society of Engineering Education Annual Meeting*, Nashville, TN, June 2003, pp. 1504-1512.

Composite materials are widely becoming the material of choice for many structural and nonstructural applications. For instance, the aircraft industry has utilized composites for wing skins and other control surfaces that will provide savings in fuel consumption and weight, the shipbuilding and offshore industries have incorporated thick single skin and sandwich composites for decks and hulls as well as for masts, and in the automotive industry composite materials are used to fabricate body panels. The civil engineering community uses glass and carbon reinforced plastics in the repair aging bridges, piers, columns and other structures vital to the nation's infrastructure and economy. Exposure to the mechanics of composite materials and structures is usually reserved for the graduate student. However, many undergraduate institutions find the need to provide their students with experience with these advanced materials and have crafted courses to do so. This describes the motivation at the Naval Academy which prepares midshipmen for officer commissions in the Navy and Marine Corps. Both of these services are significantly increasing the use of composites in their land, air and sea platforms. The paper describes a dual effort to expose midshipmen to composite materials and structures. Theory of composite materials is presented in a senior-elective course in the Mechanical Engineering department. Here the midshipmen, using computational tools such as IDEAS, are taught classical lamination theory. In the Naval Architecture and Ocean Engineering Department a course focuses on fabrication and evaluation testing of marine materials, including composites.

DAWSON, Thomas H., Professor and WALLENDORF**,** Louise A., P.E., (Hydromechanics Laboratory), "Effects on Wave Statistics of Non-Equilibrium High Frequency Waves in Random Seas," *Proceedings of the 13th International Offshore and Polar Engineering Conference*, Honolulu, HI, Vol. 3, May 2003, pp. 79-83.

The spectral density of high-frequency waves of random seas is noted to vary often as frequency to the power –4, in contrast with a power –5 associated with equilibrium conditions. A standard Jonswap sea and its modification are used here to characterize, respectively, the –5th and –4th power variations. The modified Jonswap sea is shown to represent, approximately, wave properties in the Gulf of Mexico during hurricane conditions. Laboratory simulations are considered for the field measurements and for the two Jonswap seas. Results from the former indicate general success with laboratory modeling. Results from the latter indicate difference in statistics for wave periods for the two seas, but no appreciable difference in statistics for wave heights, nor in the relation between significant wave height and variance of the sea surface. Crest statistics are changes, but in a manner consistent with increased nonlinearity associated with change in mean frequency for the modified sea.

FLACK, Karen A., Associate Professor (Mechanical Engineering Laboratory), and SCHULTZ, Michael P., Assistant Professor, "Mean and Turbulent Velocity Profiles for Sandgrain Rough Surfaces," *Proceedings of the 3rd International Symposium of Turbulence and Shear Flow Phenomena (TSFP-3)*, Sendai, Japan, June 2003, pp. 129-134.

Flat plate turbulent boundary layer measurements have been made on surfaces covered with fine and coarse sandpaper. The measurements were conducted in a closed return water tunnel, over a momentum thickness Reynolds number (Re_θ) range of 3,000 to 16,000, using a two-component, laser Doppler velocimeter (LDV). The results indicate an increase in the boundary layer thickness (δ), the integral length scales, and the skin-friction coefficient (C_f) for the rough surfaces compared to the smooth wall. The roughness functions (ΔU^+) for the sandgrain surfaces agree within their uncertainty with previous results obtained using towing tank tests and similarity law analysis. For sandpaper, it appears that a single roughness length scale ($k = 0.75\ R_t$) is sufficient to characterize the physical surface. The present results indicate that the mean profiles for both the smooth and rough surfaces collapse well in velocity defect form. The Reynolds stresses also show good collapse outside the roughness sublayer when normalized with the wall shear stress.

KRIEBEL, David L., Professor, Weggel, J. R. and Dalrymple, R. A., "Independent Coastal Engineering Study of Canaveral Harbor and the Brevard County Shore Protection Project," *Proceedings of the National Conference on Beach Preservation Technology*, Ponte Vedre Beach, FL, February 2003, pp. 1-21.

An independent study has concluded that the Canaveral Harbor Federal Navigation Project has caused erosion damages to the shoreline of Brevard County extending 10 to 15 miles south of the harbor. These erosion damages have negatively impacted the Brevard County Shore Protection Project. This project was constructed in two reaches, a 9.4 mile-long North Reach immediately south of the harbor and a 3.4 mile-long South Reach located more than 20 miles south of the harbor. Erosion damages from Canaveral Harbor have occurred in the North Reach and in the region between the North and South Reaches, while the South Reach has not been adversely impacted. Despite prior beach fills, the volume of unmitigated erosion damage from the harbor in the North Reach is about 6.64 million cubic yards. This is more than two times the fill volume of 2.8 million cubic yards placed in the initial construction of the North Reach Shore Protection Project, and it is larger than the planned 50-year lifetime nourishment volume for the North Reach of 6.58 million cubic yards.

LINDLER, Keith W., Professor, and NUCKOLS, Marshall L., Professor, **"**Hydrogen Fuel Storage/Delivery for a Diver Heater Using Hydrogen Catalytic Reactions**,"** *Proceedings of Oceans 2002*, Marine Technology Society, Biloxi, MS, pp. 919-924, October 2002.

The necessity for active diver heating during long duration, cold water, swimmer delivery vehicle (SDV) operations is well established. Alternative approaches to supply this active heating requirement have covered a wide range of technologies, including thermoelectric heaters, magnesium combustion, propane/catalytic heating, and direct electrical resistive heating. While all of these methods have been shown to be capable of producing sufficient quantities of heat, each has its own inherent restrictions and interface issues when applied to an SDV operation. These issues include heater power consumption requirements that compete and detract from the power require-

ments for SDV propulsion, and heater packaging requirements in an already space-limited environment. A simple hydrogen catalytic combustion heater was tested as a breath heater for deep diving applications. The high heat production demonstrated during this testing suggested that this approach could also be used as a diver heater to potentially minimize package size and power requirements and yet meet all the diver heating requirements for long duration Spec War missions. Preliminary analysis has shown that less than 0.4 kg of hydrogen could supply the 2 kW of heat needed to sustain up to 6 divers in 0°C water for up to 6 hours. This paper investigates the various methods to store and supply the hydrogen fuel.

MAYER, Robert H., Associate Professor**,** "Rate of Return – Must We Bother?" *Proceedings of the American Society for Engineering Education 2002 Annual Conference*, Montreal, Canada, June 2002. (CD-ROM)

Rate of return (ROR) is a widely accepted criterion for determining the economic viability of an engineering project or other investment alternative. Similarly, incremental rate of return (IROR) is often used to choose the best alternative among several. Accordingly, most engineering economy textbooks provide appreciable instruction in ROR and IROR applications, often covering one or two chapters of text. As a result, computation of the ROR is certainly within the grasp of most engineering economy students. Even so, the underlying methodologies of ROR assessment and IROR selection are computationally more difficult than other economic methods, and results can be ambiguous, indeterminate and, unless used with care, misinterpreted. For example, students will often apply, without discernment, the oft-quoted decision rule, "If the ROR > MARR, accept the alternative …" and they are sometimes wrong. Since our engineering economic textbooks offer such a variety of topics, it begs the question "How much ROR (and IROR) instruction is necessary and truly beneficial for the undergraduate engineering student?" This paper explores possible answers to that question and its more pointed companion, "ROR – Must We Bother?" Advantages and potential disadvantages (and dis-benefits) of "staying the course" with the current ROR/IROR emphasis are considered. Alternatively, a more innovative trail is suggested that seeks a better balance between engineering economy fundamentals and (applied) economic decision analysis.

MAYER, Robert H., Associate Professor, "A Source (of Energy) for Garcia," *Proceedings of the American Society for Engineering Education 2002 Annual Conference*, Montreal, Canada, June 2002. (CD-ROM)

The U.S. Navy maintains a remote installation on the island of Diego Garcia in the Chagos Archipelago, Indian Ocean. This facility uses more than 65 MWh of electricity and 350 M-gal of water annually. Reliability and costs of electricity supply and fresh water quality were concerns of the Navy in 1996. Prospective contractors were invited to submit proposals for provision of these services with some encouragement to use renewable energy resources. As a capstone design project, three teams of 1st-class midshipmen (seniors majoring in ocean engineering at the U.S. Naval Academy) set about to identify and design an ocean energy system to compete, at least conceptually, with Navy contractors. These teams explored various renew-able energy sources such as ocean thermal, wave, and offshore wind energy. In four-months time, each team researched the alternatives and developed a concept design for its selected energy source. Results were presented to a Review Panel consisting of Navy representatives and ocean engineering professionals. Brief details of this capstone experience and educational opportunities in renewable ocean energies at the U.S. Naval Academy are shared later in the paper. Past developments and recent trends in renewable energy from ocean sources are this paper's principal focus. For example, France currently maintains the most significant ocean energy recovery plant - a 240-MW tidal power facility at La Rance. And, Denmark's "Energy 21" Plan calls for development of 4 GW of offshore wind power by the year 2030, sufficient to meet more than 25% of that nation's anticipated consumption of electricity.

MILLER, Paul H., Assistant Professor, "Student Research Projects for the New Navy 44 Sail Training Craft," *Proceedings of the 16th Chesapeake Sailing Yacht Symposium*, Annapolis, MD, March 2003, pp. 135-151.

Offshore-capable sail training craft (STC) specifically designed and built for the United States Naval Academy (USNA) have been a cornerstone of its seamanship training program since 1939. Currently the fourth generation of these craft is under development and this paper summarizes research projects performed by eight midshipmen in the areas of parametric design criteria, structures, appendage development and analytical tool evaluation. While the results are oriented toward the new sail training craft, they are general enough to apply to any medium-sized offshore sailing vessel.

MILLER, Paul H., Assistant Professor, "Project-Based Coursework in a Naval Architecture Curriculum," *Proceedings of the 2003 American Society of Engineering Education Annual Meeting*, Nashville, TN, June 2003, pp. 609-617.

Numerous studies have shown the benefits of incorporating design projects into engineering courses. These projects allow the students to directly apply the syllabus topics in a "hands-on" manner, while also providing the students opportunities to develop project management skills. In the small field of naval architecture little has been written of these projects. This paper presents the details of five courses using this concept in the Naval Architecture and Ocean Engineering Department (NAOE) at the United States Naval Academy (USNA). The first course is the major's intro course for sophomores where after seven weeks each student submits the specification, calculations, lines plan and construction drawings for a towing tank model. These plans are then turned over to another student to build in balsa and test. The second course is a junior-level structures course focusing on ship structures. The students design a full mid-ship section. The final three courses are at the senior-level and include an elective in marine fabrication methods and two capstone courses. In the fabrication course small student groups design, build, QA/QC and test to destruction a series of components in metal, reinforced concrete and composites. This course focuses on the benefits of design for manufacturability and instills this approach through the actual time it takes the students to design, build and document their group projects. The capstone courses include a fall semester class that has each student prepare the preliminary design of a specific small vessel. The spring semester course has student groups prepare preliminary designs of a vessel of their choice. It is the hope that these project-based courses will provide the students with a better understanding of the ship design process. Feedback on evaluation forms has been positive.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor (Mechanical Engineering Department), and JOYCE, Peter J., Assistant Professor (Mechanical Engineering Department), "Mechanical Behavior of Composite Sandwich Structures Subjected to Impact Damage," *Proceedings of the 10th US-Japan Conference on Composite Materials*, Stanford, CA, September 2002, pp. 91-100.

The compression strength of composite sandwich panels subjected to drop-weight impact damage was determined as part of an ONR-sponsored research program. A total of twenty-four specimens were tested including four control panels, which contained no impact damage. The remaining twenty specimens had varying levels of impact damage. Three impact energy levels were tested; 6 ft-lbs, 20 ft-lbs, and 35 ft-lbs, where 6 ft-lbs represents a low energy level and 20 and 35 ft-lbs both represent high energy levels in combination with two impactor sizes, 0.5 in and 1.0 in diameter. Each panel was manufactured using fiber placement technology and consisted AQII/977-3 Astroquartz/Epoxy upper and lower face sheets and HRP/F50-5.5 Flexcore core. Panel specimens were tested under edgewise compression in accordance with ASTM C-364 using a 50-kip SATEC universal testing machine. Results show that impact energy level has a strong effect on both the compressive strength and failure mode of the panel specimens while limited data for impactor size suggests that this factor is much less important. Specifically, the compressive strength decreases with an increase in impact energy level. Edgewise compressive failure of undamaged quartz/epoxy honeycomb sandwich panels is by catastrophic fiber/matrix interfacial cracking of the face sheets combined with bending-induced fiber breaks. Low impact damage as characterized by visible matrix cracking results in an insignificant change in failure mode and load. An increase to 20 ft-lbs of impact energy causes the failure to be progressive in nature and a 15% drop in the compressive strength. Even greater impact damage (35 ft-lbs) leads to catastrophic skin/core interfacial failure due to initial impact damage of the skin/core interface (unseen by visual inspection). Failure by face sheet separation (35 ft-lbs) leads to a 37% drop in the compressive strength.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor (Mechanical Engineering Department), and JOYCE, Peter J., Assistant Professor (Mechanical Engineering Department), "Residual Strength of Impact Damaged Composite Sandwich Structures," *Proceedings of the Society for the Advancement of Material and Process Engineering (SAMPE) 2003 Technical Conference*, Long Beach, CA, May 2003. (CD-ROM)

The compression strength of fiber placed quartz/epoxy honeycomb sandwich panels subjected to impact damage was determined as part of an ONR-sponsored program. A total of twenty-four specimens were tested including four undamaged control panels and twenty panels with varying levels of impact damage. Three impact energy levels were tested (8.1 N-m, 27 N-m, and 47 N-m) using two impactor sizes. Panel specimens were tested under edgewise compression in accordance with ASTM C-364. Experimental results show that impact energy level

has a strong effect on both the compressive strength and failure mode. Specifically, the compressive strength decreases with an increase in impact energy level. Edgewise compressive failure of undamaged panels is by catastrophic fiber/matrix interfacial cracking of the face sheets combined with bending-induced fiber breaks. Low impact damage as characterized by visible matrix cracking results in an insignificant change in failure mode and load. An increase to 27 N-m of impact energy causes the failure to be progressive in nature and a 15% drop in the compressive strength. Even greater impact damage (47 N-m) leads to catastrophic skin/core interfacial failure due to initial impact damage of the skin/core interface and a 37% drop in the compressive strength.

MOURING, Sarah E., Associate Professor, MILLER, Paul H., Assistant Professor, and BURNS, Victoria L., Midshipman 1/C, (USN), "Investigation into the Mechanical Behavior of Ceramicrete," *Proceedings of the 13th International Offshore and Polar Engineering Conference*, Honolulu, HI, May 2003. (CD-ROM)

Ceramicrete is a new engineering material that was developed at the Argonne National Laboratory. It is the product of an acid-base reaction between magnesium oxide (MgO; a base) and potassium hydrogen phosphate (KH_2PO_4; an acid). A binder is produced from this reaction that can be mixed with aggregate and water to form a concrete-like material. Ceramicrete then can be pumped, gunned, or sprayed with commercially available equipment (Argonne Technology Transfer: Commercialization and Licensing Opportunity, 2002). This material shows the potential for being used in nearly all applications requiring concrete. It seems especially well suited for applications in the marine environment, since previous studies show that it mixes at room temperature, sets up quickly (even during cold weather), expands slightly when it sets forming a seal, has a high compressive strength, resists corrosion, and does not absorb water (Ceramicrete, 2002). Currently, it is being investigated for use as a replacement to cement and other sealant products used during the drilling and completion of boreholes in deep offshore environments (Ceramicrete Testing Program – Cementing Solutions Inc., 2002). The cost of ceramicrete is approximately 50% more than portland cement-based concrete (Wagh, Jeong, and Singh, 2002). However, there are several potential advantages including better penetration of small areas, better performance in cold joint bonding, and better bonding to concrete and steel. This paper outlines a preliminary study examining this new and novel material focusing on the cold joint bonding in particular.

NUCKOLS, Marshall L., Professor, and VanZandt, Kirk W., "Development Of An Oxygen 'Metabolizer' To Control Oxygen Levels In The Closed Cabin Of Submarine Rescue Vehicles," *Proceedings of the 21st International Conference on Offshore Mechanics and Arctic Engineering*, Oslo, Norway, June 2002, Paper No. OMAE 2002-28039.

The U.S. Navy is committed to maintaining the capability of rescuing survivors from a disabled submarine, including situations where the disabled submarine becomes internally pressurized due to flooding, leakage of compressed gas supplies, or through use of auxiliary breathing systems. Efficient submarine rescue requires that pressurized crewmembers be decompressed more rapidly than current decompression procedures allow when using air. The Navy Experimental Diving Unit in Panama City, FL has shown that crew decompression can be accelerated significantly by pre-breathing oxygen. Unfortunately, such oxygen pre-breathing can result in oxygen buildup in the cabin atmospheres of the submarine, and/or rescue chamber through leakage around the face seal of the oxygen masks. High levels of oxygen can create hazardous conditions within the cabin atmosphere due to fire potential and/or oxygen toxicity concerns. This paper addresses the concept development of an oxygen "metabolizer" using a hydrogen catalytic reactor to consume excess oxygen within the closed cabin atmosphere of a rescue vehicle. Such a catalytic reactor has also been shown to give an effective method of reducing the level of oxygen in diver breath heating and diver whole-body heating systems.

NUCKOLS, Marshall L., Professor, and VanZandt, Kirk W., "Manned Evaluation of a Diver Heater Using Hydrogen Catalytic Reactions," *Proceedings of Oceans 2002*, Marine Technology Society, Biloxi, MS, October 2002, pp. 913-918.

The necessity for active diver heating during long duration, cold water diving operations is well established. A proof of concept study was conducted to evaluate the effectiveness of a prototype hydrogen catalytic heater to satisfy the thermal protection needs of up to six combat swimmers in long duration, cold water missions. Body weight, urinary output, and rectal and skin temperatures were measured in six U. S. Navy divers during 3 dives to ~6 m for 6 hours in 1.7°C (35°F) water temperatures. Level of thermal comfort was reported subjectively at pre-defined intervals by the test subjects. The hydrogen catalytic heater was found to be capable of delivering 2 kilowatts of active heating to up to six divers by circulating warm water through closed-circuit tubesuits at flow

rates of up to 2.8 liters per minute (0.75 gallon per minute) at suit delivery temperatures of approximately 38-39°C (100-102°F). This heating capacity was shown to be capable of doubling to 4 kilowatts by either increasing the hydrogen circuit levels between 1-2% (still below the combustible range of 4% hydrogen), or by increasing both the hydrogen and air injection rates into the heater assembly, thereby keeping the hydrogen diluted. The heater control system was shown to successfully maintain pre-set water delivery temperatures through a feedback control loop with the hydrogen injection valve. Test results suggest that while the hydrogen catalytic heater is fully capable of providing adequate levels of supplemental heating for 6 divers simultaneously, a redesign of the commercial tubesuit will be necessary to provide thermal comfort to the divers' hands and feet and to prevent a thermal short through the diver's head.

NUCKOLS, Marshall L., Professor, and Adams, T.W., "Minimizing Breathing Resistance in Passively-Controlled Semi-Closed Rebreathers," *Proceedings of Underwater Intervention 2003*, New Orleans, LA, February 2003. (CD-ROM Paper C-3-3.)

The U. S. Navy Office of Naval Research is funding research 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 (NSW) missions without the complexity and cost of electronically controlled, closed circuit rebreathers. Tests have verified model predictions and shown that respiration-coupled gas make-up concepts, presently used in some commercial semi-closed rebreathers, reduce the variation in circuit oxygen levels as diver activity levels change. From a circuit oxygen level perspective, it is apparent that this injection system can potentially offer predictable and uniform performance over the full range of diver activity levels and give predictable oxygen levels across a wide depth range. However, a primary obstacle encountered with these semi-closed rebreathers has been their unacceptably high resistive breathing efforts (work-of-breathing). This paper discusses the efforts to characterize the major source of this breathing resistance and identify potential circuit modifications that can significantly reduce their breathing resistances and work-of-breathing.

NUCKOLS, Marshall L., Professor, and Henkener, Jerry A., "Manned Evaluation of Liquid-Insulation Garments for Long-Duration, Cold Water Diving," *Proceedings of Underwater Intervention 2003*, New Orleans, LA, February 2003. (CD-ROM Paper C-3-2.)

The objective of this proof of concept study was to evaluate the effectiveness of prototype liquid insulation liners, worn beneath wetsuits and drysuits, to satisfy the thermal protection needs of combat swimmers in long duration, cold water missions. Body weight changes, and rectal and skin temperatures were recorded on U. S. Navy divers when wearing drysuits with the liquid liners during dives to approximately 6 meters for up to 4 hours in 35°F (1.7°C) water temperatures; in 55°F (12.8°C) water temperatures with wetsuits. Comparisons in thermal protection were made with the wetsuits and drysuits with, and without, the presence of the two liquid prototypes. Level of thermal comfort was reported subjectively at 30 minute intervals by the test subjects. No significant improvement in diver thermal protection was observed when the liquid liner was tested beneath wet suits, even though the liner was shown to provide additional insulation for various regions of the body in previous unmanned testing. This result is believed to be caused by an increase in water circulation within the wetsuit when the liquid liner is worn; i.e., increased suit flushing appeared to cancel any benefits from the improved liner insulation. On the other hand, divers' mean skin temperatures when wearing the liquid liner beneath a commercial dry suit improved significantly (4°C on average) when compared with skin temperatures for divers not wearing the liner. Diver surveys during and after the testing confirmed the benefits that this liner provided to their overall thermal comfort.

SCHOENWIESNER, Richard A., LCDR, USNR, and NUCKOLS, Marshall L., Professor, "The Re-Invention of Bushnell's TURTLE," *Proceedings of Underwater Intervention 2003*, New Orleans, LA, February 2003. (CD-ROM Paper J-3-3.)

The Discovery Channel, in cooperation with the UK Channel 4, is planning a documentary on the Revolutionary War submersible, *Turtle*, as a part of its "Inventing the Past" series. The *Turtle* was designed and built by David Bushnell in 1776 for the purpose of attacking the British fleet to break the blockade of New York harbor. The U.S. Naval Academy has been invited to be the primary engineering designers and testers for this project. This endeavor is being used as a mechanism for students to apply their naval engineering skills to a real-world project.

Currently, design teams are developing specifications for the hull and calculating support system and habitability requirements based on historic documentation. Teams of craftsmen from the Massachusetts College of Art will use the designs to reconstruct the *Turtle* by early 2003 using authentic period methods and techniques. Finally, in the spring of 2003, the recreated vessel will undergo testing at the Naval Academy before being used for a re-enactment of its historic mission. This paper will detail the engineering work done by the Naval Academy, the construction techniques used by the Massachusetts College of Art, and the history of David Bushnell and his submersible, *Turtle*.

SCHULTZ, Michael P., Assistant Professor, and FLACK, Karen A., Associate Professor (Mechanical Engineering Department), "Turbulent Boundary Layers over Surfaces Smoothed by Sanding," *Bulletin of the American Physical Society: Division of Fluid Dynamics 55th Annual Meeting*, Vol. 47, No. 10, p. 55.

Flat plate turbulent boundary layer measurements have been made on painted surfaces, smoothed by sanding. The measurements were conducted in a closed return water tunnel, over a momentum thickness Reynolds number (Re_θ) range of 3,000 to 16,000, using a two-component, laser Doppler velocimeter (LDV). The mean velocity and Reynolds stress profiles are compared with those for smooth and sandgrain, rough walls. The results indicate an increase in the boundary layer thickness (δ) and the integral length scales for the unsanded, painted surface compared to a smooth wall. More significant increases in these parameters, as well as the skin-friction coefficient (C_f) were observed for the sandgrain surfaces. The sanded surfaces behave similarly to the smooth wall for these boundary layer parameters. The roughness functions (ΔU^+) for the sanded surfaces measured in this study agree within their uncertainty with previous results obtained using towing tank tests and similarity law analysis. The present results indicate that the mean profiles for all of the surfaces collapse well in velocity defect form. The Reynolds stresses also show good collapse in the overlap and outer regions of the boundary layer when normalized with the wall shear stress.

WATERS, Jennifer K., Associate Professor, and Blume, Alan L., "Ensuring the Safe and Efficient Movement of Ships in Channels," *Proceedings of the 30th PIANC-AIPCN Congress*, Sydney, Australia, September 2002. (CD-ROM)

The safety and efficiency of the movement of ships in dredged channels is significantly influenced by the design and construction of the channel as well as by the extent to which the controllability of ocean going ships is considered during the ship design process. The channel design process requires consideration of both the physical and maneuvering characteristics of a "typical" or "design" ship. Although this implies that the channel should be capable of safely and efficiently accommodating the design ship, it does not mean that it can safely and efficiently accommodate all ships either in service or those that may enter service in the future. Similarly, the ship design process requires consideration of the ship's maneuverability. However, the current guidelines for ship maneuverability consider only deep water performance, and typically do not address performance in shallow or restricted water. Therefore, these guidelines do not necessarily ensure that a ship's maneuverability is adequate to safely and efficiently move through a channel. Finally, responsibility for ensuring the safe and efficient movement of a given ship in a particular channel is shared by the ship's master, the pilot aboard the vessel and regulatory agencies responsible for waterway management.

Technical Reports

DAWSON, Thomas H., Professor, "Stokes Correction for Nonlinearity of Wave Crests in Heavy Seas," U.S. Naval Academy Engineering and Weapons Division, Report # EW-06-02, September 2002.

The application of Stokes 5th order wave theory to random deep-water waves is considered in connection with nonlinearity in crest amplitudes. The theory is shown to apply, on average, to crest amplitudes and wave heights, although differences exist for individual waves as a result of variation in wave frequency. Corrections to the Rayleigh law and associated predictions of fractions of waves exceeding crest threshold levels are shown to be in close agreement with measurements for heavy seas when the significant wave height and average wave period are specified accurately.

JUDGE, Carolyn Q., Post-Doctoral Fellow, and KRIEBEL, David L., Professor, "Shallow Water Tow Tests to Investigate Rise, Trim, Squat, and Wave Elevation," U.S. Naval Academy Engineering and Weapons Division, Report # EW-03-02, August 2002.

A series of shallow water tow tests were performed to study ship-generated waves as well as ship trim and squat in various shallow water depths. The idea behind these tests was to develop an empirical or modified "Froude" number that would collapse wave height data, trim data, and ship squat (sinkage) data for different water depths. The tow tests were conducted in the 120 foot towing tank of the U.S. Naval Academy Hydromechanics Laboratory. Measurements were made of model speed, trim, rise, resistance, and wave elevation in the wake of the model. Several previously existing empirical predictive equations were compared with the squat from these tests. In addition, a new empirical equation was developed. The new predictive equation showed the best results.

MILLER, Paul H., Assistant Professor, "Composite Materials Port Security Barrier Feasibility Study," U.S. Naval Academy Engineering and Weapons Division, Report # EW-04-02, September 2002.

To provide protection from small craft attack the Navy has deployed static port security barriers (PSB) at major naval bases. The design consists of a series of mild steel floating units, each of which has three pontoons joined by a backbone structure. Although coated with a corrosion-resistant barrier paint, initial units have shown premature corrosion leading to higher-than-desired maintenance requirements. Potential solutions to this problem include improved surface preparation, material substitution or the use of a different paint system. Alternate materials include marine grade aluminum, stainless steel and composite materials. This study looked at the feasibility of composite materials for the pontoons. Composite materials used in similar marine applications were the basis for this study and preliminary structural analyses using the finite element method was performed. The design criteria for the composite PSB was identical to the current PSB. Although the goal was to identify a solution that resulted in lower weight and life-cycle costs, initial costs were deemed important. Five composite materials were chosen for final study. Two were thermoplastics commonly used in dock pontoons. The three others were polyester and vinyl ester/E-glass laminates; two consisting of chopped strand mat and the other of a mixture of mat and woven roving. Although all five appear technically feasible and meet all the design criteria, the vinyl ester and chopped strand mat pontoon was selected based on cost and other factors.

WHITE, Gregory J., Professor, "Resistance, Seakeeping, and Wave Survey Testing of the 2200 LT MCM(XH) HYSWAS Hull Form," U.S. Naval Academy Engineering and Weapons Division, Report # EW-01-03, February 2003.

Maritime Applied Physics Corporation (MAPC) has developed a unique hull-form for a new mine counter-measures ship with a very high-speed capability. This hull form is a modified version of the one tested by the Naval Academy's Hydromechanics Laboratory (NAHL) in May of 2001. The modifications allow the ship to operate in shallower waters while still retaining the high-speed capability. The modifications included a decrease of the hullborne draft, reshaping the underwater hull, and a redesign of the underside of the cross-deck structure. Three model test series have been performed to provide MAPC with foilborne powering and wake information, and wave loading information when foilborne at high speeds. This information will facilitate the design of the propeller for the ship and provide some information to help evaluate the foilborne seakeeping performance of the ship. For the Effective Horsepower (EHP) Test and Wave Loading Test the model was configured without foils. The foil resistance was calculated separately and added to the measured resistance. During the Wake Survey the foils were attached to the model to insure that the flow field in the vicinity of the propeller location was correctly scaled. For all of the tests the model was held rigidly in place at the desired draft and trim, and measurements were recorded for vertical force, drag force, and encounter wave amplitude. The model draft corresponded to a full-load condition of 1,400 LT (foilborne). The model trim varied between 0° and 3° (bow up) as prescribed in the test plan.

WHITE, Gregory J., Professor, and Hill, John R., "Effective Horsepower Model Testing of an 18th Century Sailing Warship: USS Constitution (IX-21)," U.S. Naval Academy Engineering and Weapons Division, Report # EW-05-03, May 2003.

The U.S. Naval Academy's Class of '51 Gallery of Ships contains a collection of British Dockyard Models of 16th through 19th century naval vessels. These models, built by dockyard craftsmen contemporaneously with their full-scale counterparts, are considered by experts to be accurate reproductions of the ships they represent.

This permits the models to be used for research on the evolution of warship design during this period when most of the technical developments in sailing warships occurred. Historic sailing warships, however, have hull forms unlike modern vessels. They tended to be shorter, beamier, with shallower drafts, and very full, rounded bows. Therefore, the guidelines that exist for turbulent stimulation on scale models (Ridgely-Nevitt, 1967) needed to be evaluated in its application to these very different hull forms traveling at relatively slow speeds. The experiment documented in this report is the first step in an attempt to establish guidelines for determining the appropriate scale-model size and the placement of turbulent stimulation on historic sailing warships.

Presentations at Professional Meetings and Conferences

Bigio, D., University of Maryland, and MOURING, Sarah E., Associate Professor, "Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS) Intermediate Modules," *BESTEAMS Workshop I and Workshop II*, U.S. Naval Academy, Annapolis, MD, February 2003.

DAWSON, Thomas H., Professor, "Effects on Wave Statistics of Non-Equilibrium High Frequency Waves in Random Seas," 13th International Offshore and Polar Engineering Conference, Honolulu, HI, May 2003.

KRIEBEL, David L., Professor, "Ship-Generated Waves," 28th International Conference on Coastal Engineering, Cardiff, Wales, United Kingdom, July 2003.

KRIEBEL, David L., Professor, "Independent Coastal Engineering Study of Canaveral Harbor and the Brevard County Shore Protection Project," National Conference on Beach Preservation Technology, Ponte Vedra, FL, February 2003.

KRIEBEL, David L., Professor, "An Overview of Sediment Transport Sections of the New *Coastal Engineering Manual,*" a short course sponsored by the American Society of Civil Engineers and presented at the Woods Hole Oceanographic Institution, Woods Hole, MA, June 2003.

KRIEBEL, David L., Professor, "Impacts of Canaveral Harbor on the Beaches of Brevard County," Brevard County Board of Commissioners, Melbourne, FL, September 2002.

MAYER, Robert H., Professor, "Rate of Return – Must We Bother?" American Society for Engineering Education 2002 Annual Conference, Montreal, Canada, June 2002.

MAYER, Robert H., Professor, "A Source (of Energy) for Garcia," American Society for Engineering Education 2002 Annual Conference, Montreal, Canada, June 2002.

MAYER, Robert H., Professor, "A Source (of Energy) for American Samoa," Renewable Energy Workshop, American Samoa, November 2002.

MAYER, Robert H., Professor, "U.S. Naval Academy Education," The Atlantic Center for Innovative Design and Control of Small Ships, National Naval Responsibility Initiative Workshop, Hoboken, NJ, December 2002.

MILLER, Paul H., Assistant Professor, "Vessel Stability Characteristics and Risk Management," U.S. Coast Guard Auxiliary Northern Area Workshop, Edgewater, MD, February 2003.

MILLER, Paul H., Assistant Professor, Bogataj, P., and Laiosa, J., "Computational Fluid Dynamics for Small Craft Design," International Boatbuilding Exhibition & Conference, Ft. Lauderdale, FL, February 2003.

MILLER, Paul H., Assistant Professor, "Student Projects for the New Navy 44," Chesapeake Sailing Yacht Symposium, St. John's College, Annapolis, MD, March 2003.

MILLER, Paul H., Assistant Professor, "Development of Stability Standards and What They Mean to Users," Safety-at-Sea

Seminar, U.S. Naval Academy, Annapolis, MD, March 2003.

MOURING, Sarah E, Associate Professor, "Engineering and Conflict Resolution," Research Internships in Science and Engineering Program, University of Maryland, College Park, MD, July 2002.

MOURING, Sarah E, Associate Professor, BURKHARDT, John A., Associate Professor (Mechanical Engineering Department), KARPOUZIAN, Gabriel N., Professor (Aerospace Engineering Department), and JOYCE, Peter J., Assistant Professor (Mechanical Engineering Department), "Composites at USNA," South Carolina Research Authority (SCRA) Meeting, U.S. Naval Academy, Annapolis, MD, July 2002.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor (Mechanical Engineering Department), and JOYCE, Peter J., Assistant Professor (Mechanical Engineering Department), "Mechanical Behavior of Composite Sandwich Structures Subjected to Impact Damage," 10th US-Japan Conference on Composite Materials, Stanford, CA, September 2002.

MOURING, Sarah E., Associate Professor, and JOYCE, Peter J., Assistant Professor (Mechanical Engineering Department), "Composites in the Navy," South Carolina Research Authority (SCRA) Technology Transfer Centers Composites Consortium Meeting, Washington, DC, January 2003.

MOURING, Sarah E., Associate Professor, and Louca, L., "Residual Strength of Composite Panels," Office of Naval Research Workshop, Lansdowne, VA, April 2003.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor (Mechanical Engineering Department), and JOYCE, Peter J., Assistant Professor (Mechanical Engineering Department), "Residual Strength of Impact Damaged Composite Sandwich Structures," Society for the Advancement of Material and Process Engineering 2003 Technical Conference, Long Beach, CA, May 2003.

MOURING, Sarah E., Associate Professor, MILLER, Paul H., Assistant Professor, and BURNS, Victoria L., 1/C Midshipman, (USN), "Investigation into the Mechanical Behavior of Ceramicrete," 13th International Offshore and Polar Engineering Conference, Honolulu, HI, May 2003.

NUCKOLS, Marshall L., Professor, "Development Of An Oxygen 'Metabolizer' To Control Oxygen Levels In The Closed Cabin Of Submarine Rescue Vehicles," 21st International Conference on Offshore Mechanics and Arctic Engineering, Oslo, Norway, June 2002.

NUCKOLS, Marshall L., Professor, "Manned Evaluation of a Diver Heater Using Hydrogen Catalytic Reactions," Oceans 2002, Marine Technology Society, Biloxi, MS, October 2002.

NUCKOLS, Marshall L., Professor, "The Re-Invention of Bushnell's *Turtle*," Annapolis Civitan Club, U.S. Naval Academy Speakers Bureau, Annapolis, MD, January 2003.

NUCKOLS, Marshall L., Professor, "Manned Evaluation of Liquid-Insulation Garments for Long-Duration, Cold Water Diving," Underwater Intervention 2003, New Orleans, LA, February 2003.

NUCKOLS, Marshall L., Professor, "The Re-Invention of David Bushnell's *Turtle*," 2003 Raouf Memorial Lecture, U. S. Naval Academy, Annapolis, MD, February 2003.

Schmidt, L., Schmidt, J., Bigio, D., Lent, R., University of Maryland, MOURING, Sarah E., Associate Professor, Wilkens, G., Morgan State University, and Gloster, C., Howard University, "Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS) Module Training for ENES 100," College Park, MD, August 2002.

Schmidt, L., Schmidt, J., Bigio, D., Lent, R., University of Maryland, MOURING, Sarah E., Associate Professor, Wilkens, G., Morgan State University, and Gloster, C., Howard University, "Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS) Introductory Module Training," Howard University, Washington, DC, January 2003.

SCHULTZ, Michael P., Assistant Professor, "Comparison of the Hydrodynamic Performance of Fouling-Release Surfaces with Copper-Based Antifouling Coatings," Office of Naval Research Environmental Quality Workshop, Annapolis, MD, June 2002.

SCHULTZ, Michael P., Assistant Professor, "Comparison of the Hydrodynamic Performance of Fouling-Release Surfaces with Copper-Based Antifouling Coatings," Office of Naval Research Biofouling Control Workshop, San Diego, CA, July 2002.

SCHULTZ, Michael P., Assistant Professor, "Turbulent Boundary Layers on Surfaces Covered with Marine Algae," 11th International Congress on Marine Corrosion and Fouling, San Diego, CA, July 2002.

SCHULTZ, Michael P., Assistant Professor, and FLACK, Karen A., Associate Professor (Mechanical Engineering Department), "Turbulent Boundary Layers over Surfaces Smoothed by Sanding," 55th Annual Meeting of the American Physical Society: Division of Fluid Dynamics, Dallas, TX, November 2002.

SCHULTZ, Michael P., Assistant Professor, Finlay, John A., Callow, Maureen E., and Callow, James A., "Three Models to Relate the Detachment of Low Form Fouling at Laboratory and Ship Scale," 11th International Congress on Marine Corrosion and Fouling, San Diego, CA, July 2002.

WATERS, Jennifer K., Associate Professor, and Blume, Alan L., "Ensuring the Safe and Efficient Movement of Ships in Channels," PIANC 30th Congress, Sydney, Australia, September 2002.

WATERS, Jennifer K., Associate Professor, "The Atlantic Center for the Innovative Design and Control of Small Ships – USNA Developments," Office of Naval Research, National Naval Responsibility Initiative Meeting, Stevens Institute of Technology, Hoboken, NJ, December 2002.

WATERS, Jennifer K., Associate Professor, "The Atlantic Center for the Innovative Design and Control of Small Ships – Team Objectives and Progress," Office of Naval Research, National Naval Responsibility Initiative Meeting, National Education Research Consortium (NERC) Meeting / MIT Cambridge, MA, April 2003.

WATERS, Jennifer K., Associate Professor, "The Atlantic Center for the Innovative Design and Control of Small Ships – USNA Effort Update," Office of Naval Research, National Naval Responsibility Initiative Meeting, University College of London, London, UK, June 2003.