Celebrating the 50th Anniversary!

United States Naval Academy

Trident Scholar Presentations and Banquet

25-27 April 2013

FOREWORD

The Naval Academy instituted the Trident Scholar Program in 1963 to provide an exciting opportunity for some of our most capable students to engage in extended independent study and research throughout their senior year. And this year is a special one—it marks the 50th anniversary of this elite program!

Under the Trident Scholar program, midshipmen in the top 10 percent of their class at the end of the first semester of their junior year are invited to submit research project proposals for evaluation by a committee composed of senior-level professors and officers who represent all academic departments. Based on their academic qualifications and the findings of this Trident Scholar committee, the Academic Dean and Provost appoints new Trident Scholars for the next academic year.

Each midshipman selected to participate in the Trident Scholar program is afforded an unusually exciting and unique educational experience. A Trident Scholar's research is carried out independently, but is also under the close watch of faculty advisers who are all well qualified in the subject field of study. Each Scholar's academic class load is adjusted to allow for the significant time that they will spend on their research project, while at the same time allowing them to complete the requirements of their regular academic major. Special funding provided by the Office of Naval Research (ONR) for the Trident Scholar program helps to make certain that materials, instrumentation, and travel opportunities are available to each scholar. ONR's generous help ensures that each student's experience is as educationally complete and as rewarding as possible.

Traditionally, at the end of each academic year each Trident Scholar presents the results of his or her research in a lecture at an Academy conference, in a written archived report, and in a poster session prior to a formal dinner. The conference and dinner bring together the entire spectrum of Naval Academy research, including graduating as well as newly designated scholars, their advisers and sponsors, members of the Trident committee and other invited guests. From the work presented by the scholars each year, one is selected as the most outstanding research project. This midshipman is awarded the *Office of Naval Intelligence Harry E. Ward Trident Scholar Prize*.

Many Trident Scholars are given the opportunity to undertake immediate graduate studies at other universities prior to reporting to their first duty assignment. Many also complete advanced degrees during their time on active duty and return later in their careers for teaching assignments at the Naval Academy.

Let me use this opportunity to congratulate the Trident Scholars of the Class of 2013 for their great individual achievement, and pass along my wishes for their continued success throughout their naval careers and beyond.

A.T. PHILLIPS
Academic Dean and Provost

Celebrating 50 Years!

2013 TRIDENT SCHOLAR COMMITTEE

Committee Chair
Professor Maria J. Schroeder
Associate Director of Midshipman Research

Division of Engineering and Weapons
Associate Professor Jim S. Cowart
Associate Professor Matthew G. Feemster
Associate Professor David W. Fredriksson

Division of Mathematics and Science
Associate Professor Christopher W. Brown
Associate Professor Clare E. Gutteridge
Professor Mark E. Kidwell

Division of Humanities and Social Sciences
Captain Craig C. Felker
Professor Nancy A. Mace
Associate Professor Thomas A. Zak

We honor those former Trident Scholars who attained flag rank and served their Navy and their Nation at the highest levels.

ADM Donald Lee Pilling, USN (Ret.)
Class of 1965
Vice Chief of Naval Operations

RADM Robert Michael Nutwell, USN (Ret.)
Class of 1966
Deputy Director Space, Information Warfare, Command and Control

VADM John Scott Redd, USN (Ret.)
Class of 1966
Director, Strategic Plans and Policy
Office of the Joint Chiefs of Staff

ADM Richard Willard Mies, USN (Ret.)
Class of 1967
Commander in Chief
United States Strategic Command

VADM George Peter Nanos, Jr., USN (Ret.)
Class of 1967
Commander, Naval Sea Systems Command

RADM Jay Martin Cohen, USN (Ret.)
Class of 1968
Chief of Naval Research

RADM Jeffrey Alan Cook, USN (Ret.)
Class of 1968
Vice Commander, Naval Air Systems Command

VADM Evan Martin Chanik, USN (Ret.)
Class of 1973
Commander, Second Fleet
Director, Combined Joint Operations from the Sea Center of Excellence

RADM Paul John Ryan, USN (Ret.)
Class of 1973
Commander, Mine Warfare Command

VADM Joseph Ambrose Sestak, Jr., USN (Ret.)
Class of 1974
Deputy Chief of Naval Operations
Warfare Requirements & Programs (N6/N7)

RADM Samuel J. Cox, USN
Class of 1980
Director, National Maritime Intelligence-Integration Office Commander, Office of Naval Intelligence

RADM William Hunter Hilarides, USN
Class of 1981
Special Assistant for Research, Strategy and Integration for Information Dominance (OPNAV N2/N6)

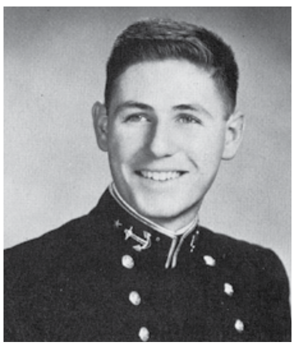
ADM John Michael Richardson, USN
Class of 1982
Director, Naval Nuclear Propulsion Program

1963-2013

This year marks the 50th Anniversary of the Trident Scholar Program at the U.S. Naval Academy.

The U.S. Naval Academy instituted the Trident Scholar Program in 1963 to provide an opportunity for exceptionally capable midshipmen to engage in independent study and research during their senior year. Over its long history, 488 midshipmen have participated in the program, contributing their talents, creativity, and enthusiasm to their field of study. Below is the first class of Trident Scholars.

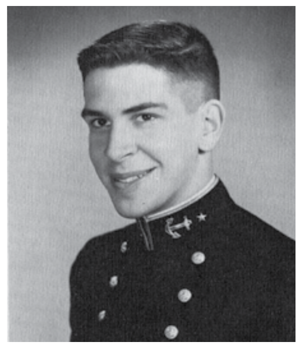
TRIDENT SCHOLARS, 1963-1964



LEON PRESTON BROOKS, JR.
Jacksonville, Florida

Some Electron Radiation Effects on Transistors – A Data Re-Presentation Technique

Faculty Advisor: Assistant Professor Gary L. Buckwalter, Science Department



MELVILLE HENRY LYMAN, III
Glen Ridge, New Jersey

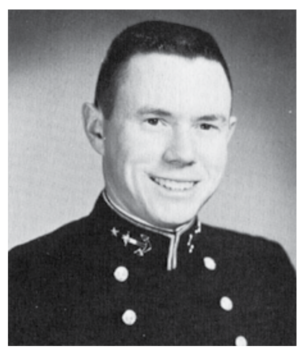
Analysis of Methods of Position Determination in Actual Use in the Navy

Faculty Advisor: Commander William Beck, Jr., USN, Naval Science Department

CLARK GRAHAM
Jacksonville, Florida

Boundary Layer Control by Distributed Damping with Special Reference to Reducing Drag on a Submarine Hull

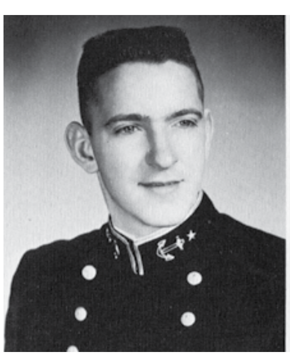
Faculty Advisor: Assistant Professor Tadeusz Kowalski, Engineering Department



BARRY MERRILL PLOTT
Scottsdale, Arizona

A Study of the Value and Advisability of Quasi-Military Activities of the U.S. Navy in Latin America

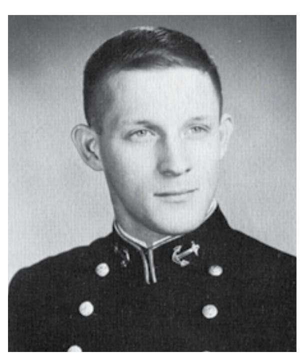
Faculty Advisors: Professor John R. Probert, English, History and Government Department, and Associate Professor Lloyd W. Buhrman, Foreign Languages Department



(Ψ) **BOBBY JOE HAYNES**
Watauga, Tennessee

Synthesization of Heteropolytungstates and Determination of Their Physical and Chemical Properties

Faculty Advisor: Associate Professor Orville W. Rollins, Science Department



JEFFRY VANCE WILSON
Kansas City, Kansas

Study of Fire-Control Problems for Lasers Used as Weapons

Faculty Advisor: Lieutenant Commander Russell N. McDowell, USN, Weapons Department

Celebrating 50 Years!

TRIDENT SCHOLAR PRESENTATIONS—Celebrating 50 Years!

Moderator
Professor Maria J. Schroeder
Associate Director of Midshipman Research

Thursday, April 25, 2013

0800-1100 and 1300-1600
Rickover Hall, Room 103

Morning Session

0800

Midshipman First Class Mitchell R. Graves

An Algorithm to Identify and Localize Suitable Dock Locations from 3-D LiDAR Scans

A LiDAR, or Light Detection and Ranging, sensor is a laser array that provides a high definition depth map, or point cloud, of its surroundings. The goal of this project is to create an algorithm that will automatically identify and locate suitable maritime docking locations from such data.

0845

Midshipman First Class Zachary M. Patrick

Pointing and Jitter Control for the USNA Multiple-Beam Combining System Using H-Infinity Adaptive Control with Video Sensor Feedback

The ability to accurately combine energy from multiple low power laser beams on a specific target is critical to making directed energy weapons effective and practical in the near term. This project will apply an adaptive optimal controller to the USNA multiple-beam combining system using a high-speed video camera to provide feedback for control algorithms.

0930

Midshipman First Class Andrew J. Rydalch

Turbulent Boundary Layer Flow over Superhydrophobic Surfaces

Navy ships experience viscous drag, friction between the ship and the water, which decreases a ship's energy efficiency. The objective of this project was to determine whether this drag could be reduced by using modified surfaces. The effectiveness of specific surfaces at reducing viscous drag was determined through velocity measurements.

1015

Midshipman First Class Matthew P. Christian

Numerical Model for Predicting and Managing Heat Dissipation from a Neural Probe

Local stimulation of neural tissue using novel light emitting neural probes is being investigated and developed for use in understanding neural pathways. This project focused on modeling the subsequent heating of the neural tissue and exploring methods to minimize the affected area.

1100-1300 Break

Afternoon Session

1300

Midshipman First Class Max C. Van Benthem

Tow Tank Measurements of Hydrodynamic Performance of a Horizontal Axis Tidal Turbine Under Unsteady Flow Conditions

Ocean tides are a potential source of renewable energy. Tidal turbines can harness this energy, but a complete analysis of their performance has not been performed. This project assesses the effects of surface waves on the performance characteristics of a model horizontal axis tidal turbine and characterizes the near wake flow structure under these conditions.

1345

Midshipman First Class Jennifer L. Jones

An Evaluation of the Corrosion and Mechanical Performance of Interstitially Surface Hardened Stainless Steel

The goal of this project was to characterize, validate and quantify the long-term performance of surface hardened stainless steel using various corrosion and mechanical tests. These tests focused on measuring mechanical properties important for marine applications. These results address specific concerns regarding possible degradation in mechanical properties due to the surface hardening process.

1430

Midshipman First Class Peter A. Roemer

Stochastic Modeling of the Persistence of HIV: Early Population Dynamics

Mathematical modeling of biological systems is crucial to effectively and efficiently developing treatments for medical conditions that plague humanity. This project examines a model of the initial stages of HIV infection. We examine the conditions that determine viral persistence and improve the model by incorporating the innate randomness of the physical world.

1515

Midshipman First Class Caitlin M. Fine

Structural Changes and Convective Processes in Tropical Cyclones as seen in Infrared and Water Vapor Satellite Data

In this study, tropical cyclone eye and eyewall radii, as well as outwardly propagating convective waves, were identified, and their impacts on tropical cyclone intensity and dynamical processes investigated. The eye radius varies as the tropical cyclone experiences different internal cycles. The radial minimum IR brightness temperatures in the eyewall were moderately negatively correlated to TC cyclone intensity, especially during periods of significant intensity change. The outwardly propagating waves resemble waves that have been linked in literature to structural and dynamical changes in tropical cyclones.

TRIDENT SCHOLAR PRESENTATIONS—Celebrating 50 Years!

Moderator
Professor Maria J. Schroeder
Associate Director of Midshipman Research

Friday, April 26, 2013
0800-1145
Rickover Hall, Room 103

Morning Session

0800
Midshipman First Class Kyle A. Elam
Isolation of Thermal and Strain Responses in Composites using Embedded Fiber Bragg Grating Temperature Sensors

Fiber Bragg grating (FBG) optical temperature sensor arrays are embedded in a composite to rapidly detect localized temperature gradients in the structure. Since the sensors respond to both strain and temperature variations, methods to discriminate between each response have been explored, to include both architectural and signal processing techniques.

0845
Midshipman First Class Nicholas R. LaSalle
Study of Passive Flow Control for Ship Air Wakes

Shipboard helicopter operations are constrained by the air wake created by the ships' superstructure. Passively modifying the air flow over a ship can lead to a more favorable operational envelope. Analysis of a passive flow control technique is performed using numerical simulations, wind tunnel testing, and in situ testing.

0930
Midshipman First Class Andrew C. Tresansky
Numerical Modeling of High Irradiance Electromagnetic Beam Effects on Composite and Polymer Materials

The goal of this project was to produce a transient heat transfer model to predict the effect of high energy laser heating on monolithic polymers and carbon fiber reinforced polymer composites. These materials were then experimentally tested with a high energy laser, and the computational model was compared to the experimental results.

Morning Session (continued)

1015
Midshipman First Class Phoebe M. Kotlikoff
Estimating the Effects of Pre-College Education on College Performance

This paper assesses the effects of post-secondary education on college success by using a large detailed cross-sectional dataset of students from the U.S. Naval Academy. We find that students who have attended a pre-college program tend to graduate at higher rates than comparable students entering directly from high school, but perform at lower levels academically overall.

1100
Midshipman First Class Christopher D. Galvin
Effect of Unsteady Wakes on Turbine Tip Gap Leakage

The objective of this project is to determine the effects of unsteadiness on aerodynamic losses in a gas turbine engine. This unsteadiness may be caused by the wakes of upstream blades, or by leakage flows around the tips of turbine blades. Pressure and velocity fields were measured in a model turbine passage in a wind tunnel. The relationship between pressure loss and velocity fields will be used to determine the effects of wakes on tip gap leakage.

Celebrating 50 Years!

TRIDENT SCHOLAR BANQUET

★ ★ ★ ★ ★

Trident Banquet and Induction Ceremony
Saturday, April 27, 2013
Alumni Hall

Poster Session and Social Hour
1800-1900

Master of Ceremonies
Dr. Andrew T. Phillips
Academic Dean and Provost

Invocation
Lieutenant Madison Carter, CHC, USN
5th Battalion Chaplain

Guest Speaker
Mark Gorenflo
Principal Director to the
Deputy Under Secretary of the Navy
(Plans, Policy, Oversight & Integration)

Award of Trident Scholar Certificates to Class of 2013 Trident Scholars

Induction of Trident Scholars for the Class of 2014

MARK GORENFLO

Principal Director to the
Deputy Under Secretary of the Navy
(Plans, Policy, Oversight & Integration)

Mark Gorenflo is the Principal Director to the Deputy Under Secretary of the Navy for Plans, Policy, Oversight & Integration [DUSN (PPOI)]. The DUSN (PPOI) serves as the Secretary of the Navy's primary advisor on foreign and defense policy; intelligence; capabilities and readiness; and the Department of the Navy's security enterprise. He was appointed to this position in July 2009.

Mr. Gorenflo was first appointed to the Senior Executive Service as the Deputy Assistant Secretary for Policy for the Department of Veterans Affairs in April 2008. From September 2007 to April 2008, he served as Acting Principal Director for Forces Transformation & Resources for the Assistant Secretary of Defense for Special Operations/Low Intensity Conflict & Interdependent Capabilities. From August 2005 to August 2007, Mr. Gorenflo served as the Director of Communications for the 7th Vice Chairman of the Joint Chiefs of Staff, Admiral E. P. Giambastiani, USN. His first appointment in the Civil Service was as the Director of the Commander's Advisory Group for the Supreme Allied Commander Transformation/Commander U.S. Joint Forces Command in Norfolk, Virginia from October 2004 to August 2005.

From 1983 to 2004, Mr. Gorenflo served as a submariner in the United States Navy, retiring as a Commander. During his Navy career, he served aboard USS Norfolk (SSN 714); USS Montpelier (SSN 765) as new construction Engineer; USS Georgia (SSBN 729)(Blue) as Executive Officer; and commanded USS Parche (SSN 683).

Mr. Gorenflo graduated with distinction from the United States Naval Academy in 1983, where he received a bachelor's of science degree (majoring in english) as a Trident Scholar.* He went on to study politics and philosophy as a Rhodes Scholar from the University of Oxford. Mr. Gorenflo has been awarded the CJCS Joint Distinguished Civilian Service Award, the Defense Superior Service Medal and the Legion of Merit with Gold Star, among other personal, unit and campaign awards. He is a Life Member and an award winning author of the U.S. Naval Institute and the Naval Submarine League.

***MARK LOUIS GORENFLO**, Fox Mill, Virginia
Milton and the 'New Philosophy': An Historical-Literary Exploration of the Relationship Between Science and the Humanities in the 17th Century
(Report #125)
Faculty Advisor: Assistant Professor John C. Wooten, *English Department*

Celebrating 50 Years!

MATTHEW PAUL CHRISTIAN

Midshipman First Class
United States Navy

Numerical Model for Predicting and Managing Heat Dissipation from a Neural Probe

photo by Gin Kai, USNA Photo Lab

Stimulation of neural tissue using novel light emitting neural probes is being investigated and developed for use in understanding neural pathways in the brain. Embedding the light source in the probe will result in local heat generation that could easily damage tissues under study, creating inaccurate results. A model has been created using COMSOL for the thermal effects of these probes in the brain. The model includes blood perfusion and metabolic processes and was used to investigate the effect of different probe geometries on temperature excursion. The model indicated that the maximum temperature change should increase with insertion depth and decrease as the area of the heat source is increased. The model was also used to study the effect of extending the probe length beyond the heat source, which resulted in a significant reduction in temperature excursion. This model was compared to physical tests using a 0.65% agar gel as a neural tissue simulant in a temperature controlled environment. Sample microprobes containing a thin-film resistive heating element at their tip were designed and fabricated. The resistive element of the probe acted both as a heat source and as a calibrated temperature sensor. The COMSOL model was modified to include the effects of flow through a porous medium to simulate active cooling with an injected saline solution. The model included vascular uptake of the saline into the bloodstream. The combination of the model and physical test platform provide a means for testing the thermal effects of different probe designs and quantifying the limitations of heat generation within the probe.

FACULTY ADVISERS

Associate Professor Samara L. Firebaugh
Electrical and Computer Engineering Department
B.S.E., Princeton University
M.S., Ph.D., Massachusetts Institute of Technology

Associate Professor Andrew N. Smith
Mechanical Engineering Department
B.M.E., Villanova University
Ph.D., University of Virginia

External Collaborator: Dr. Brian Jamieson, Scientific & Biomedical Microsystems, LLC

KYLE ASPIE ELAM
Midshipman First Class
United States Navy

Isolation of Thermal and Strain Responses in Composites using Embedded Fiber Bragg Grating Temperature Sensors

photo by Gin Kai, USNA Photo Lab

In this research, fiber Bragg grating (FBG) optical temperature sensors are used for structural health monitoring of composite materials. The specific goal is to detect the thermal response of a composite to high energy radiation incident on the surface of a composite structure. The unique optical characteristics of FBG sensors permit rapid detection of highly localized temperature gradients in a host structure, making FBGs well-suited for this application.

However, since the FBG sensors respond to axial strain in the optical fiber, any structural strain experienced by the composite is also detected. Thus the embedded FBG sensors respond to the mechanical strain in addition to any thermal effects. Consequently, this research has focused both on identifying the unique characteristics of each response and on developing feasible methods to isolate the thermal response from the strain response. This ensures that any response to mechanical strain does not mask the response to a temperature gradient present on the composite surface. The test specimen built for this work is a three-dimensional array of FBG temperature sensors embedded in a carbon/epoxy composite structure.

There are two techniques used to isolate the thermal and strain responses in this research. First, the embedded three-dimensional FBG array is an architectural strategy that incorporates both in-plane and through-thickness sensor arrays. This architectural component exploits the spatial differences between the temperature profile and the strain profile in a composite structure. Second, an accompanying signal processing scheme is used to interpret and identify each response. Both techniques will be presented, and the degree to which this strategy increases the functionality of FBG temperature sensors in mechanically strained composite structures will be assessed. Finally, opportunities for continued research in this topic area will be discussed.

FACULTY ADVISERS

Associate Professor R. Brian Jenkins
Electrical and Computer Engineering Department
B.S., M.S., The Ohio State University
Ph.D., University of Colorado at Boulder

Associate Professor Peter J. Joyce
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B.S., University of Illinois (Urbana-Champaign)
M.S., Ph.D., The University of Texas at Austin

Associate Professor Deborah M. Mechtel
Electrical and Computer Engineering Department
B.S., The University of Virginia
M.S., Ph.D., The Johns Hopkins University

CAITLIN MARIE FINE
Midshipman First Class
United States Navy

Structural Changes and Convective Processes in Tropical Cyclones as Seen in Infrared and Water Vapor Satellite Data

photo by Gin Kai, USNA Photo Lab

In the western North Pacific Ocean, tropical cyclone (TC) hazards, including strong winds, storm surge, high waves, and heavy rainfall threaten archipelagos, densely crowded coastlines, and naval forces ashore and afloat. To accurately forecast TC track, intensity, and radii of 34-, 50-, and 64-kt winds out to 120 hours, meteorologists at the Joint Typhoon Warning Center (JTWC) must start from a thorough understanding of the TC's current structure. To accomplish this mission, they rely heavily upon satellite observations, particularly measurements in the water vapor (WV) and infrared (IR) channels on geostationary satellites. Unlike their counterparts in the Atlantic basin, however, JTWC forecasters do not have an aircraft reconnaissance program to take in-situ measurements of TCs. Therefore, it is critical to develop products that identify key TC structures in geostationary satellite data and track them over time, as these data are often the only real-time information available to the forecasters.

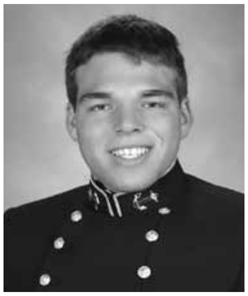
This project examined satellite brightness temperatures in the WV and IR channels in typhoon-strength TCs during the 2012 season to first identify the eye, eyewall, and deep convection, and then to investigate the evolution of those features over time. The eye radius, which fluctuates as the tropical cyclone undergoes internal cycles, including eyewall replacement, was defined in this study as the location of the steepest gradient in two satellite products: (1) IR brightness temperatures, and (2) the difference in brightness temperatures between WV and IR channels. The eyewall, which contains the strongest winds and deepest convective clouds, was defined in this study as the location of the radial minimum IR brightness temperatures, indicating the tallest and coldest clouds, as well as the location of the radial maximum WV-IR brightness temperature differences, indicating the location of deepest convection. The TC intensity was found to be moderately negatively correlated with infrared brightness temperatures, and moderately positively correlated with WV-IR brightness temperature differences, especially during challenging-to-predict periods of intensification or decay. In addition to the eye and eyewall radii, outward propagating convective waves were identified in both WV and IR data. These waves had similar phase speed and wavelength as those found by other recent studies to be relevant to dynamical processes that control the tropical cyclone, offering another potentially useful tool to identify and predict TC structural changes.

FACULTY ADVISERS

Commander Elizabeth R. Sanabia, USN, Permanent Military Professor
Oceanography Department
B.S., U.S. Naval Academy
M.S., Ph.D., Naval Postgraduate School

Assistant Professor Bradford S. Barrett
Oceanography Department
B.S., University of North Carolina at Chapel Hill
M.S., Ph.D., University of Oklahoma

External Collaborators: Jeffrey D. Hawkins, Naval Research Laboratory, Monterey, CA
Christopher S. Velden, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison, Madison, WI



CHRISTOPHER DEAN GALVIN

Midshipman First Class
United States Navy

Effect of Unsteady Wakes on Turbine Tip Gap Leakage

photo by Gin Kai, USNA Photo Lab

Gas turbine engines are an essential source of power in the modern world. Gas turbines are found in military and civilian aircraft, ships, and power plants. Because of this widespread use, relatively small improvements in efficiency have a large cumulative impact on energy use. The most significant source of loss and inefficiency in a gas turbine engine is tip gap leakage. Tip gap leakage occurs when flow travels across the top of the turbine blade through the small clearance space between the blade tips and the turbine casing, instead of along the length of the turbine blades. Tip gap leakage reduces the load on the turbine blades and the flow that is leaked across the tip gaps is wasted. Additionally, tip gap leakage leads to vortices that result in dissipated rotational kinetic energy and can disrupt the flow in the next stage of the turbine. Tip gap vortices also interact with the rest of the flow moving through the turbine passage, further complicating the flow pattern. In order to study to the full effects of tip gap leakage, the flow through a turbine must be modeled including the effect of wakes from blades in upstream stages of the engine.

Experimental methods are used to study the effects of unsteadiness on gas turbine tip gap leakage. A case with steady flow and no tip gap is used as a baseline to compare the results of the other cases. The flow patterns are studied for each of the cases and compared to see the effects of unsteadiness on tip gap vortices and end wall flows.

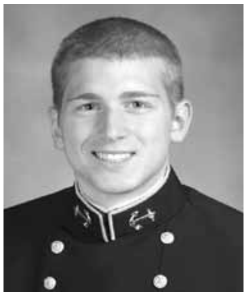
The total pressure loss is found for each case and related to the energy dissipated by secondary aerodynamic losses. Additionally, the dynamic pressure is recorded at various places along the blades. The effects of the wakes on the velocity of the flow are shown by phase averaging velocity data. The velocity and turbulence of phases in and outside of the wake are compared to find the effect of the wake. Additionally these phases are compared to a case with steady flow. The effects of wakes on total pressure loss are found by comparing cases with wakes to cases without wakes. This study will use Particle Image Velocimetry, PIV, to collect velocity fields upstream of the blades, inside the blade passage and in the plane perpendicular to the flow downstream of the blades. These data could be used in the future to help limit the negative effects of tip gap leakage and make gas turbine engines more efficient.

FACULTY ADVISERS

Professor Ralph J. Volino
Mechanical Engineering Department
B.S., Michigan State University
M.S., Ph.D., University of Minnesota

Assistant Professor Cody J. Brownell
Mechanical Engineering Department
B.S.E., Duke University
M.S., Ph.D., The Johns Hopkins University

Celebrating 50 Years!



MITCHELL ROBERT GRAVES
Midshipman First Class
United States Navy

An Algorithm to Identify and Localize Suitable Dock Locations from 3-D LiDAR Scans

photo by by Gin Kai, USNA Photo Lab

Unmanned vehicles have established an important place in the modern battlefield. They play a key role in intelligence and surveillance while not putting human lives in harm's way. The United States Navy recognizes this, has created The Navy Unmanned Surface Vessel (USV) Master Plan, which lists autonomous launch and recovery (L&R) as a key challenge.

A necessary enabling technology is the ability to automatically identify L&R sites from sensor data. This project focuses on the identification of suitable docking sites from three dimensional LiDAR scans. A LiDAR, or Light Detection and Ranging, sensor is a sensor that collects range images from a rotating array of vertically aligned lasers.

Our solution leverages open source C++ code from Point Cloud Library—"a standalone, large scale, open project for 2D/3D image and point cloud processing." Given a LiDAR point cloud our identification algorithm proceeds as follows. First the RANSAC algorithm is used to isolate horizontal planar surfaces that may belong to the dock. Then using all the points that are not part of the planar surface, Euclidean Cluster Recognition is used to isolate clusters that could be potential vertical pilings. Bayes' Theorem is used to compute the probability that each cluster matches the characteristics of piling. For each candidate piling, the origin of that cluster is compared to the location of the target dock's planar surface. The dock can be identified by the relation of the pilings location to the dock's planar surface. The final output of the algorithm will be a sub-set of points, isolated from the original cloud, that are hypothesized to correspond to the dock.

FACULTY ADVISER

Associate Professor Joel M. Esposito
Weapons and Systems Engineering Department
B.S., Rutgers University
M.S., Ph.D., University of Pennsylvania

JENNIFER LYNN JONES
Midshipman First Class
United States Navy

An Evaluation of the Corrosion and Mechanical Performance of Interstitially Surface Hardened Stainless Steel

photo by Gin Kai, USNA Photo Lab

A surface hardening technique called "interstitial hardening" has been developed to introduce interstitial carbon atoms into stainless steel surfaces without the formation of carbides. Surface hardening of machine elements such as impellors or fasteners would improve performance regarding cavitation and galling resistance, and has intensified interest in this process.

The interstitial hardening technique involves an activation step where the protective oxide film is removed from the surface in order to allow appreciable diffusion of the interstitial atom into the material at temperatures below which precipitate phases will form. Commercial processes have been developed to do this using halogen gases or plasma. However, there remains a need to characterize and validate the specific performance characteristics of the hardened materials. The stability of the hardened surface and the reproducibility of the process on various substrates need to be verified. In particular, the process parameters for which the corrosion resistance of the stainless steel is retained, rather than degraded, is of particular interest for marine applications.

This project incorporated experimental testing conducted on 316L stainless steel that has been surface hardened using available commercial techniques, using both carbon and nitrogen as the interstitial atom. The hardness and thickness of the surface hardened layer is characterized and compared using metallography and microhardness profiling. The corrosion performance of the hardened surface is assessed using electrochemical potentiodynamic testing to determine the pitting potential in 3.5 wt. % NaCl solution. Corrosion fatigue and slow strain rate testing of untreated, hardened and damaged, hardened surfaces exposed to ASTM seawater is conducted. Finally, critical galling stresses are determined and compared. Post-test examination of damage attempts to identify mechanisms of material failure and characterize how corrosion-assisted cracks initiate and grow in surface-hardened materials.

FACULTY ADVISERS

Associate Professor Michelle G. Koul
Mechanical Engineering Department
B.A., University of Virginia
M.S., Ph.D., State University of New York at Geneseo

Associate Professor Joel J. Schubbe
Mechanical Engineering Department
B.S., U.S. Air Force Academy
M.S., Ph.D., U.S. Air Force Institute of Technology

PHOEBE McDANIEL KOTLIKOFF

Midshipman First Class
United States Navy

Estimating the Effects of Pre-College Education on College Performance

College graduates in the United States tend to have significantly higher earnings and higher labor participation rates than their counterparts with only high school degrees. Yet despite the rising importance of college education, there is growing concern that many college entrants are unprepared to succeed in undergraduate studies, contributing to higher drop-out rates and weaker performance among students pursuing bachelor's degrees. One approach in addressing this problem has been to select certain students into pre-college programs to give them a better chance to succeed in college. This paper examines the returns to participation in pre-college remedial education after controlling for intrinsic student ability.

photo by Gin Kai, USNA Photo Lab

We used a large cross-sectional dataset of students from the graduating classes of 1988 – 2011 from the U.S. Naval Academy, categorizing students into those who have attended a pre-college program such as the Naval Academy Prep School, a foundation school, or another college prior to the Naval Academy, and those entering directly from high school. Using a combination of propensity score matching and regression discontinuity to mitigate selection bias, we determine the empirical relationships between assignment to a post-secondary education program and future success in college.

Results show that pre-college programs have positive returns to graduation rates across the board. However, in terms of course grades, results indicate that the cohort of prep school students perform better than their direct entry counterparts only in their first semester. This is followed by no returns, and in some cases negative returns, to the prep school programs in subsequent semesters when considering a range of outcome variables. Moreover, the cohort that attends pre-college programs tends to graduate with a significantly lower overall class rank. This study provides insights into how pre-college programs can be reshaped to enhance the future performance of their participants.

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Study of Passive Flow Control of Ship Air Wakes

photo by Gin Kai, USNA Photo Lab

Helicopter flight operations on naval vessels are limited to specific flight envelopes to ensure the safety of the pilot and aircraft. These flight envelopes are developed based upon helicopter operating capabilities and the impact of air wakes on the aircraft. Since Naval Academy training vessels, known as YPs, have similar superstructure and deck configurations as a modern cruiser or destroyer, comparisons can be made between YP air wakes and those of larger naval surface ships. A dedicated YP has been modified with a flight deck and hanger structure to create an air wake similar to that of a modern destroyer.

This project examines the effects of passive flow control techniques aimed at reducing the impact of ship air wakes on naval rotary wing aircraft flight operations. Passive flow control techniques such as fences and deflectors around the hanger face and flight deck could potentially alter air wake flow structures and help control the severity of the ship air wake. For this investigation, notched fences have been placed along the top and sides of the hanger face, angled aft at 30 degrees to vertical, and along the starboard flight deck, angled out board.

Air wake data is collected in-situ onboard YP 676, from a 4% scale wind tunnel ship model, and from computational fluid dynamics (CFD) simulations. In-situ measurements are compared with wind tunnel and CFD results to validate the accuracy of the simulations and to quantify any alterations in the air wake and its associated flow structures. Data collected from this investigation should provide a method for investigating how to decrease the impact of air wakes on rotary wing aircraft.

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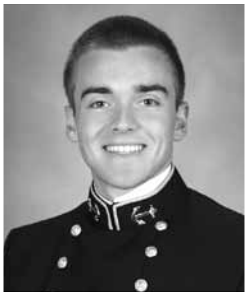

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Pointing and Jitter Control for the USNA Multiple-Beam Combining System Using H-Infinity Adaptive Control with Video Sensor Feedback

photo by by Gin Kai, USNA Photo Lab

The ability to accurately combine energy from multiple low power beams on a specific target is critical to making directed energy weapons effective and practical. At the United States Naval Academy Directed Energy Research Center, a project is underway to develop a three beam combining system that employs fast steering mirrors (FSMs) for pointing and jitter control of individual beams. In the previous work, an adaptive H-infinity optimal controller has been developed to control a single beam using a beam position detector for feedback.

This project will apply the H-infinity adaptive controller to the multiple-beam combining system in a multiple-input, multiple-output feedback control environment. Instead of using a position detector, a high-speed video camera will be employed to provide centroid estimation and feedback for pointing control algorithms.

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Stochastic Modeling of the Persistence of HIV: Early Population Dynamics

photo by Gin Kai, USNA Photo Lab

Mathematical modeling of biological systems is crucial to effectively and efficiently developing treatments for medical conditions that plague humanity. Systems of differential equations are the traditional tools used to theoretically describe the spread of disease within the body. In this project we consider the dynamics of the Human Immunodeficiency Virus (HIV) in vivo duringthe initial stages of infection.

Both mathematical and biological results support the idea that contact with the HIV retrovirus does not automatically imply permanent infection. Given factors such as the CD4+ T-cell growth rate, infection rate, and viral clearance rate, it is possible to correctly predict the end viral state in a deterministic model. While this is useful, such a model lacks the randomness inherent in physical processes and parameter estimation. To account for this, our project examines both discrete and continuous stochastic models for the early stages of HIV infection. These models are crafted using the knowledge of biological interactions and fundamental mathematical principles.

We also examine the well-known three-component deterministic model in greater detail, proving existence and uniqueness of the solutions. Furthermore, we prove that solutions remain biologically meaningful, i.e., are positivity preserving, and perform a thorough stability analysis for the equilibrium states of the system. Finally, we develop two new stochastic models and obtain extensive numerical results to measure the probability of infection given the transmission of the virus to a new individual. To simulate the dynamics of the virus, we employ a number of computational methods for ordinary and stochastic differential equations, including Runge-Kutta methods and the Euler-Maruyama scheme.

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United States Navy

Turbulent Boundary Layer Flow over Superhydrophobic Surfaces

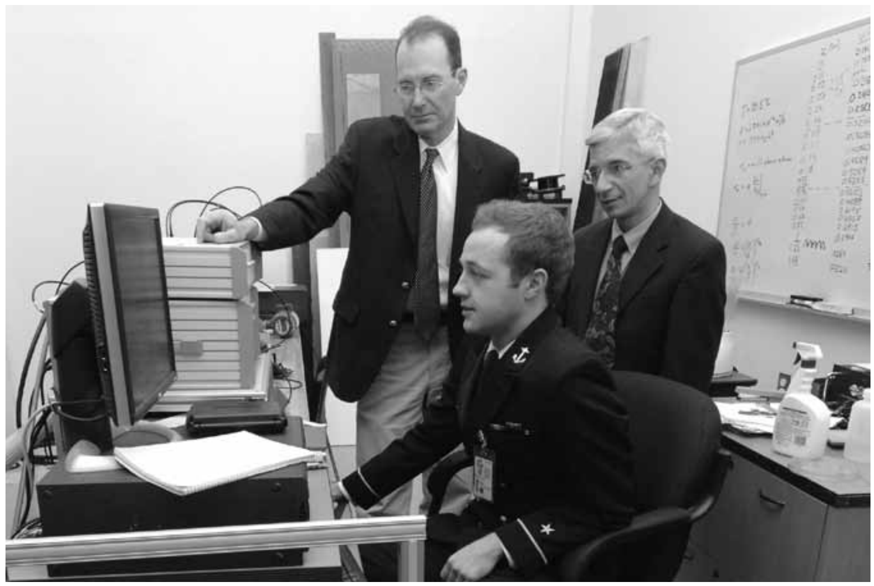

photo by Gin Kai, USNA Photo Lab

Drag is a force that opposes motion. This force affects objects moving through any viscous fluid, such as a plane moving through the air, a car driving down the road (through air), and a ship traveling through water. Based on an object's geometry and velocity, it experiences different forms of viscous drag as it moves through a fluid medium, characterized by the Reynolds number. At low Reynolds numbers, the flow is typically laminar while higher Reynolds numbers result in more turbulent flows characterized by disturbances such as eddies. In most practical applications where drag is a major factor, such as a ship sailing through the water, the Reynolds numbers are high and the flow is turbulent.

The objective of this project was to determine whether drag caused by turbulence in boundary layer flow can be reduced through the use of modified surfaces. This study encompassed the testing of four different surfaces: 1) Teflon SLIP, 2) Aluminum SLIP, 3) Aluminum Superhydrophobic, and 4) Honeycomb Superhydrophobic. Each of these surfaces uses specific geometrical surface features saturated with another fluid to modify the original water-surface interface. Due to the influence of the Green Fleet Initiative and the Navy's goal to increase the fleet efficiency, the Office of Naval Research is interested in determining the effectiveness of these surfaces in boundary layer flow under operating conditions similar to those in which Navy ships operate with fully developed turbulence. The objective of this study was to provide data and analysis detailing the effect of these modified surfaces on boundary layer turbulence and drag reduction.

The testing was conducted in the small water tunnel in the USNA Hydromechanics Laboratory which operates in boundary layer flow conditions capable of producing fully developed turbulence. The effect of the surfaces on turbulence and drag reduction was characterized using Laser Doppler Velocimetry (LDV). Velocity data from the LDV were used to characterize the performance under specific flow conditions for each of the modified surfaces. The performance of each surface was compared with the performance on a smooth wall in similar operating conditions to characterize the effectiveness of each modified surface.

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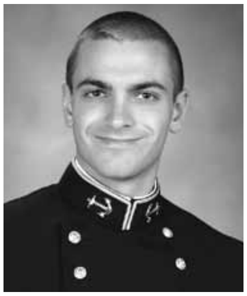

ANDREW CHRISTOPHER TRESANSKY
Midshipman First Class
United States Navy

Numerical Modeling of High Irradiance Electromagnetic Beam Effects on Composite and Polymer Materials

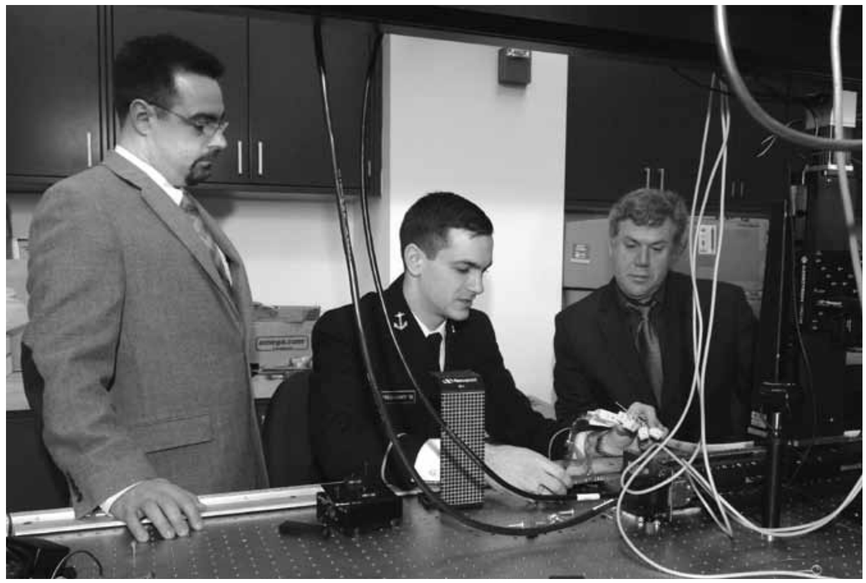

photo by Gin Kai, USNA Photo Lab

High Energy Lasers (HEL) are being developed as potential Directed Energy Weapons for the U.S. Navy. In order to best employ this technology, the effect of these HELs on materials needs to be understood. There have been extensive studies on the effects of lasers on materials, as well as the modeling of these effects but this research focuses on the irradiance and wavelength regime of current interest to the U.S. Navy.

Using material property inputs determined using Differential Scanning Calorimetery (DSC) and Fourier Transform Infrared Spectroscopy (FTIR) a physics-based computer model was developed using COMSOL. The model is used to predict the temperature field, heat affected zone and through thickness drilling that HEL irradiation causes in polymer and composite materials.

Since laser heating causes ablation, material removal had to be included in the model. Material removal in the model was accomplished by actuating the material properties of ablated nodes to make them behave as if they had been removed. This was done by using Heaviside functions to actuate the material property functions over experimentally determined ablation temperature ranges. Material removal is usually accomplished by remeshing after each time step and removing ablated nodes, which creates complex topographies and is computationally expensive.

The model was validated by experiments in the USNA Directed Energy Research Center An easy to model polymer, PMMA, and more complicated carbon fiber composite were irradiated with an IPG Photonics fiber coupled laser. Front face, rear face, and internal temperatures were recorded and the burn rate was measured. The model predictions were compared to the experimental data and a sensitivity analysis was conducted on the model. The model was then iterated to higher accuracy by improving the mesh density, material properties and model geometry. Moving forward, this model could be expanded to incorporate multi-physics to more fully describe the effects of HEL on materials as well as on structures yielding predictions with even greater accuracy.

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Tow Tank Measurements of Hydrodynamic Performance of a Horizontal Axis Tidal Turbine Under Unsteady Flow Conditions

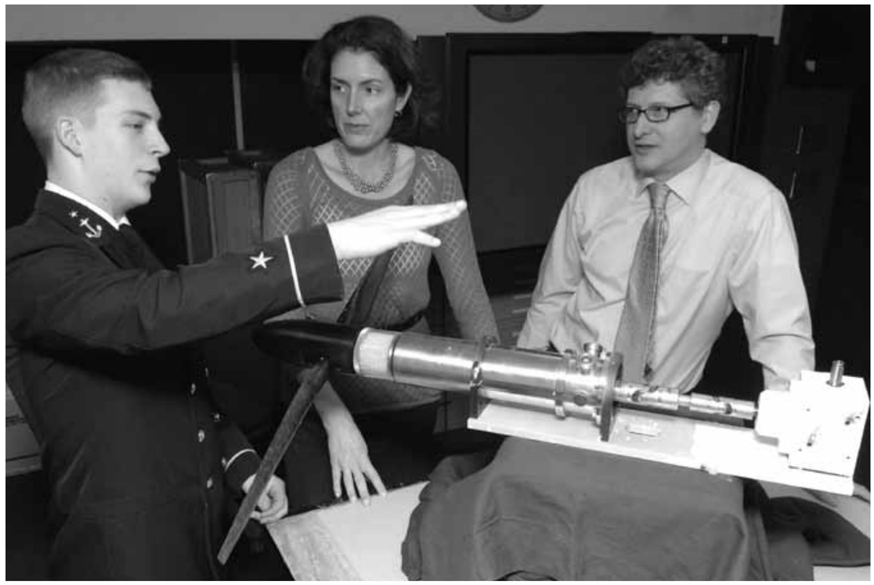

photo by Gin Kai, USNA Photo Lab

Tidal turbines utilize the kinetic energy of water resulting from ocean tidal flows to generate power. This type of power generation is a potential source of clean, reliable renewable energy. However, the technology is still being developed. The effects of unsteady flow conditions, specifically surface waves, on tidal turbines have not been completely analyzed. This Trident project examines the effects of waves on the performance characteristics of a model horizontal axis tidal turbine selected by the Department of Energy and designed by the National Renewable Energy Laboratory (NREL).

The performance characteristics of a 1/25th scale model horizontal axis tidal turbine were tested under unsteady flow conditions. The experiments were conducted in the large tow tank facility at the United States Naval Academy Hydromechanics Laboratory. Parameters including wave height, wave length and tow speed for the experiment were scaled to properly model flow conditions that a horizontal axis tidal turbine was expected to experience at a full scale. Two different experiments were conducted. First, turbine rotational speed, torque and thrust were measured for unsteady flow conditions characterized by a range of incoming waves. Wave types were varied to represent different flow conditions. Turbine performance characteristics, including thrust and power coefficients, were obtained as functions of rotor tip speed ratio for the unsteady flow conditions tested. Power generation was also presented as a function of wave phase. All measurements were taken at a 700 Hz sampling rate as the waves passed over the turbine. The data were used to analyze the effects of waves on turbine performance. The second experiment involved a detailed fluid flow survey in the near wake of the turbine for one of the waves utilized in the first experiment. Fluid flow was measured using Acoustic Doppler Velocimeters sampling at 200 Hz. The results of this experiment provided a characterization of velocity fields in the near wake of the turbine, necessary information for the placement of multiple turbines in a larger array. The results of this project have potential for application in the civilian sector and U.S. Navy power generation.

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We are proud to announce the United States Naval Academy Class of 2014 Trident Scholars.

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Applications of Graph-Theoretic Tests to Change Detection

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External Collaborator: Asst. Prof. Jeffrey T. Leek, Department of Biostatistics, The Johns Hopkins University

MIDSHIPMAN 2/C MARK A. COLBY
Aerospace Engineering (Astro) Major

Modeling the Ship Air Wake/Rotor Dynamic Interface

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MIDSHIPMAN 2/C BRENDAN C. EGAN
Mechanical Engineering Major

Pitching Flexible Propulsors: Experimental Assessment of Performance Characteristics

Advisers: Assoc. Prof. Mark M. Murray, Mechanical Engineering Department, and Asst. Prof. Cody J. Brownell, Mechanical Engineering Department

MIDSHIPMAN 2/C ERIC N. FUGLEBERG
Systems Engineering (Honors) Major

An Experimentally Derived Mathematical Model and Control of a Joint-Actuated, Free-Floating Buoy

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MIDSHIPMAN 2/C GRANT N. GENZMAN
Ocean Engineering Major

Analysis of the Loads on and Dynamic Response of a Floating Flexible Tube in Waves and Currents

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MIDSHIPMAN 2/C CHRISTOPHER B. HOUSE
Electrical Engineering Major

Sonic Actuation of Small-Scale Robots in a Fluidic Environment

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MIDSHIPMAN 2/C MATTHEW J. LANOUE
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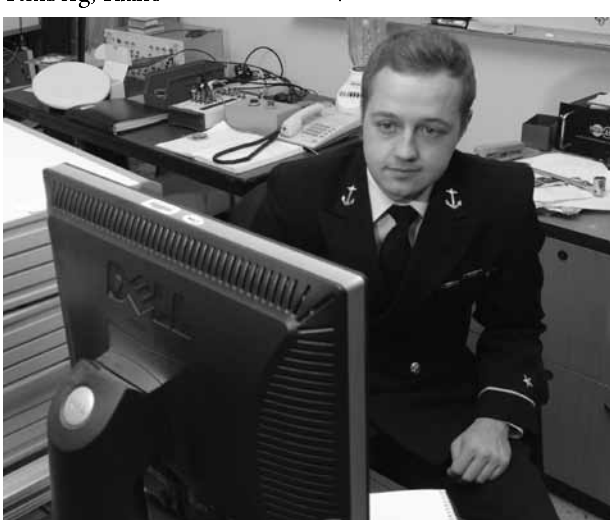

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