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**DIGITAL TARGET IMAGING ARCHITECTURE FOR MULTIPLE LARGE TARGET GENERATION**

Associate Professor Douglas J. Fouts, Department of Electrical and Computer Engineering

Professor Phillip E. Pace, Department of Electrical and Computer Engineering

**Introduction**

Modern shipboard and airborne wideband inverse synthetic aperture radars (ISARs) are capable of generating images of target objects. Such imaging capability is an advantage over previous technology because it improves the ability to identify the specific type of target, distinguish friend from foe, accurately guide weaponry, and defeat electronic protection such as false target decoys. Thus, modern wideband imaging ISARs create a difficult ship defense problem. For example, if an adversary is using a wideband imaging ISAR, an electronic protection system cannot synthesize a false target by just transmitting a signal that emulates a radar return off a single or a few scattering surfaces. Instead, such a transmitted signal must emulate a coherent sequence of reflections with proper delay, phase, and amplitude that is similar to what would come from the multiple scattering surfaces at multiple ranges (distances from the radar) of an actual ship.

The existing state-of-the-art technology for generating false radar targets includes the use of acoustic charge transport (ACT) tapped delay lines and fiber optic tapped delay lines. ACT devices are no longer commercially available and also have limited bandwidth, making them impractical against wideband imaging radars. Optical devices are bulky and costly to manufacture, especially for the longer delay line lengths needed to synthesize a false target image of even a moderate-size ship. Furthermore, neither of these older technologies is easily and quickly reprogrammed. Thus, a false target image generated with these techniques cannot be changed quickly enough to emulate a moving ship on the ocean. At best, these techniques are only useful for calibration and testing of ISARs.

**Technical Approach**

The equations and algorithms needed to digitally synthesize a false target radar image have evolved considerably over the last several years, primarily through research conducted by Associate Professor Douglas J. Fouts, Professor Phillip E. Pace, and their thesis students (12 M.S. in Combat Systems, Electronic Warfare, and Electronic Systems Engineering and one Ph.D. in Electrical Engineering) in the Center for Joint Services Electronic Warfare in the Department of Electrical and Computer Engineering at the Naval Postgraduate School. Simulations proved the equations and algorithms correct. A system-level architecture was then developed for a new type of digital radio frequency memory (DRFM) that could be interfaced to digital hardware capable of generating a false target radar image. The architecture of the digital

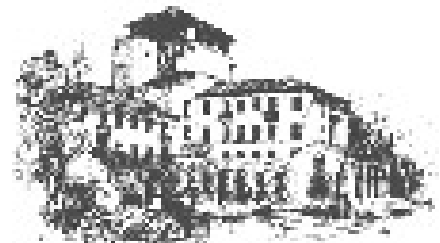
--continued on page 2

**IN THIS ISSUE**

Featured Projects..... 1, 4  
 Research Center ..... 8  
 Student Research..... 12  
 USNA Feature ..... 17  
 Project Notes..... 20  
 Relationships..... 22  
 Chair Professorships ..... 24  
 Agreements..... 25  
 Short Courses..... 26  
 Faculty News ..... 29  
 Student Theses ..... 45  
 Directories ..... 48

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# FEATURED PROJECT

## DIGITAL TARGET IMAGING ARCHITECTURE, *continued from page 1*

image synthesizer (DIS) was then developed. Simulations on the architecture proved it would work and allowed the performance to be estimated. A digital circuit was then designed to implement the new DIS architecture. This was a true team effort between the two principal investigators and a dedicated group of graduate students performing such tasks

as simulating the architecture, designing circuits, capturing schematic diagrams with a CAD system, and simulating the circuits to confirm proper operation and to determine operating speed. When finished, the circuit implemented a scaled-down, proof-of-concept version of the new architecture with

*--continued on page 3*

### About the INVESTIGATORS

**Douglas J. Fouts** is an Associate Professor in the Department of Electrical and Computer Engineering at the Naval Postgraduate School. He also holds a joint appointment with the Space Systems Academic Group. Dr. Fouts is the 2002 recipient of the Carl E. and Jesse W. Menneken Award for Excellence in Scientific Research. This annual award recognizes recent highly meritorious research having identifiable impact on Navy or DoD technology and is intended especially for the encouragement and benefit of younger faculty members.



**Douglas J. Fouts**

Since his arrival at NPS in September 1990, Professor Fouts has conducted numerous research projects in the general area of very large scale integrated-circuits (VLSI) and microelectronic system design. With primary DoD/DoN funding, some of his research topics include Gallium Arsenide (GaAs) and Indium Phosphide (InP) digital integrated-circuit design, radiation tolerant and radiation hardened integrated-circuit design for space applications, high speed/low-power GaAs and InP logic circuits, and fault-tolerant microprocessor systems for space application. Dr. Fouts has been very successful at involving his students in his research, having advised or co-advised over sixty masters thesis and two doctoral students during his tenure at NPS. His publication record of thirty-three refereed journal and conference papers and four U.S. patents is outstanding.

Dr. Fouts received his Ph.D. and masters in Electrical and Computer Engineering from the University of California at Santa Barbara and his undergraduate degree from the University of California at Berkeley. He is a member of the Institute for Electrical and Electronics Engineers

(IEEE), the American Radio Relay League (ARRL), and the Peninsula Brass Quintet.

**Phillip E. Pace** is a Professor in the Department of Electrical and Computer Engineering at the Naval Postgraduate School. He received the B.S. and M.S. degrees from the Ohio University in 1983 and 1986 respectively, and the Ph.D. from the University of Cincinnati in 1990 --- all in electrical and computer engineering. Prior to joining NPS, he spent two years at General Dynamics Corporation, Air Defense Systems Division, as a design specialist in the Radar Systems Research Engineering department. Before that, he was a member of the technical staff at Hughes Aircraft Company, Radar Systems Group, for five years. Professor Pace was selected for the Outstanding Research Achievement Award in 1994, 1995 and 1998 for his work at the Naval Postgraduate School in electronic warfare and signal processing and received the Association of Old Crows 1995 Academic Training Award. Dr. Pace has been the Chairman of the Navy's Threat Simulator Validation Working Group since October 1998 and was



**Phillip E. Pace**

a participant on the Navy's NULKA Blue Ribbon Panel in January 1999. He is the author of the textbook *Advanced Techniques for Digital Receivers*, Artech House Inc. 2000, and has been a principal investigator on numerous research projects in the areas of signal processing, electronic warfare, and weapon systems analysis. He is a member of the International Society for Optical Engineering (SPIE), Association of Old Crows (AOC) and a senior member of the IEEE.

## FEATURED PROJECT

### DIGITAL TARGET IMAGING ARCHITECTURE, *continued from page 2*

8 range-bin processors. An integrated circuit (IC) fabrication mask was then designed and verified that incorporated all 8 range-bin processors onto a single chip. The Office of Naval Research (ONR) paid for chip fabrication at HP/Agilent using an 0.5 micron CMOS process with 4 layers of interconnect. After fabrication, the chip was tested at the NPS. It

worked perfectly and at a clock speed higher than expected. The ONR then provided additional funding to design a full-scale, custom IC to implement the full digital image synthesizer architecture with 512 range-bin processors on a single chip (DIS-512). The design of the DIS-512 is a very large

*--continued on page 33*

### A DIGITAL ASIC FOR SYNTHESIZING FALSE TARGET RADAR IMAGES

Modern inverse synthetic aperture radars (ISARs) are capable of generating images of targets. Figures 1a and 1b show a photograph of the *USS Crockett* and an image of the ship from a U.S. Navy AN/APS-137 ISAR. Such imaging capability is an advantage over previous technology because it improves the ability to identify the specific type of target, distinguish friend from foe, accurately guide weaponry, and defeat electronic protection such as false target decoys. This creates a difficult ship defense problem because traditional methods for generating false target decoys emulate radar returns off a single or a few scattering surfaces and thus cannot create an image. To create an image, a transmitted signal must emulate a coherent sequence of reflections with the proper delay, phase, and amplitude that is similar to what would come from the multiple scattering surfaces at multiple ranges (distances from the radar) of an actual ship.

A wideband chirp waveform from a modern ISAR has a complex signal that can be described by

$$s(t) = \text{rect}\left(\frac{t}{T}\right) e^{j2\pi\left(f_c t + \frac{Kt^2}{2}\right)}$$
$$\text{rect}\left(\frac{t}{T}\right) = \left\{ \begin{array}{ll} 1 & \text{for } \frac{t}{T} < \frac{1}{2} \\ 1 & \text{for } \frac{t}{T} < \frac{1}{2} \end{array} \right\}$$

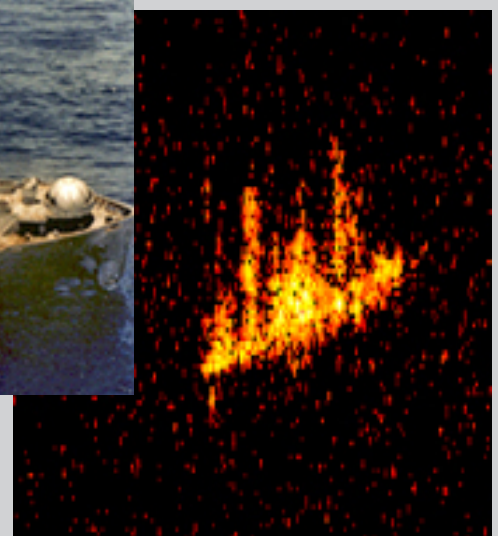
where  $t$  is time,  $T$  is the pulse width,  $f_c$  is the carrier frequency,  $K$  is the chirp rate, and  $D$  is the linear frequency sweep or the bandwidth of the transmitted signal. With the interception of such a signal, a realistic false target radar image can be digitally synthesized using the system shown in Figure 2. The heart of the system is the full-custom, all-digital, ASIC described in this paper, which is referred to as the digital image synthesizer (DIS). Referring to Figure 2, the received wideband chirp waveform is down converted

*--continued on page 33*



Figure 1a (above). *USS CROCKETT*

Figure 1b (right). Images of *USS CROCKETT* from a U.S. Navy An/APS-137 inverse synthetic aperture radar.





# FEATURED PROJECT

## HOW OPTIMIZATION GUIDES ARMY BASE CLOSURE AND REALIGNMENT

Associate Professor Robert F. Dell, Department of Operations Research  
LTC William J. Tarantino, USA, Center for Army Analysis

In the 1990s, the Army closed 139 of its bases in the U.S., saving an estimated \$3.1 billion. The next round of military Base Realignment and Closure (BRAC) will be in 2005. Optimal Stationing of Army Forces (OSAF) is an optimization-based decision support model adopted by the Army to guide its 2005 BRAC. OSAF's journey to adoption spans a decade of experience using optimization for Army stationing.

### Army Stationing and BRAC

The Army frequently plans how to station its force structure, just as a large corporation plans how to best produce its products at plants worldwide. For example, OSAF recently suggested potential locations for rotary wing training, and also determined a new home for the U.S. Army Southern Command. The Army is legislatively much more encumbered in its closure decisions than a corporate counterpart. A complex, politically insulated process for closing and realigning military installations is provided by Title XXIX of Public Law 101-510 (the National Defense Authorization Act for Fiscal Year 1991) as amended. This act established an independent Defense Base Closure and Realignment Commission and set in motion a process known as BRAC for 1991, 1993, and 1995 to be applied to installations in the U.S. The law authorizing these three rounds has been remarkably successful in allowing the Department of Defense (DoD) to eliminate excess infrastructure [Government Accounting Office 2001]. Since 1995, the DoD has urged Congress to authorize additional BRAC rounds and in 2002 received authorization for a round in 2005. The Army will use OSAF to help plan its 2005 BRAC.

### OSAF Overview

OSAF prescribes an optimal Army stationing plan for a given force structure, set of installations, available implementation dollars, and stationing restrictions. Each stationing plan satisfies many unit requirements and is evaluated with a set of quantitative and qualitative metrics that include realignment and closure costs. Reviews by Army leadership and over 60 presentations to Army general officers and their civilian counterparts over the last two years have helped us decide what stationing restrictions, unit requirements, and quantitative metrics to include, what can be ignored, and what is better left for posterior expert judgment; in making these

decisions, we must frequently balance tradeoffs between detail and tractability.

The Army has long used integer linear programming (see definition below) to help make stationing decisions and Naval Postgraduate School faculty and student research have played a significant role. Dell et al [1994] describes some early work. Gezer [2001] and Bayram [2002] are recent theses that report integer linear programs to help with Army stationing and infrastructure consolidations. Dell [1998] and recent theses by Oremis [2000] and Ardic [2001] report integer linear programs to help the Army implement BRAC decisions.

Optimal Stationing of Army Forces (OSAF) includes an integer linear program that can be expressed in the following form:

$$\begin{array}{ll} \text{minimize}_x & cx \\ \text{subject to} & Ax = b, x \geq 0, \\ & x_j \in \{0,1\} \forall j \in R, \end{array}$$

where  $c$  and  $x$  are  $n$ -vectors,  $b$  is an  $m$ -vector,  $A$  is an  $m \times n$  matrix, and  $R$  is an index set of binary variables. An instance of the program is specified by the data ( $c$ ,  $b$ , and  $A$ ). For a typical OSAF instance,  $m$  is about 44,000,  $n$  is about 70,000, and the cardinality of the set  $R$  is about 2,800. Connors, Dell and Tarantino [2002] provide additional detail.

### OSAF Installations and Units

The Army categorizes its installations by primary mission and OSAF addresses units stationed at five different installation types in the U.S. that share similar characteristics:

- maneuver,
- command and control,
- professional schools,
- major training areas, and
- training schools.

OSAF includes each installation's available heavy and light maneuver training capacity, ranges, and facilities, and unit requirements for these assets. For 2009, we have a force structure consisting of more than 3,500 major units on over 60 installations and training areas, as well as 11 major leased facilities. We also include National Guard and Reserve Component requirements.

--continued on page 5

## FEATURED PROJECT

### HOW OPTIMIZATION GUIDES ARMY BASE CLOSURE AND REALIGNMENT, *continued from page 4*

The Army divides its building types and ranges on each installation into 353 facility category groups (FCGs), which are inventoried in an Army Real Property Planning and Analysis System. However, only a handful of these 353 FCGs provide the majority of the square footage units require and that have been significant factors in past stationing studies. For example, 25 FCGs include 80% of all square feet of buildings in the Army, while 50 FCGs include approximately 90%.

Most OSAF model instances consider 39 FCGs aggregated into the following nine groups:

- operations,
- administrative,
- aviation maintenance,
- vehicle maintenance,
- supply and storage,
- training instruction (active force),
- community facilities,
- unique facilities, and,
- enlisted unaccompanied housing.

The Installation Status Report provides a quality rating (green for good, yellow for fair, and red for poor) for each square foot of each FCG at each installation. OSAF combines

these groups into green and other and insures that any unit moved to a new installation is given green-rated facilities or new construction. If only other-rated facilities are available, an upgrade cost is applied to upgrade existing facilities to green. OSAF does not upgrade the facilities for units that remain on an installation (units that do not move) and assumes that green-rated facilities are the last ones to be evacuated by units leaving an installation.

OSAF uses metrics from the Installation Training Capacity/Army Range Requirements Model (ITC/ARRM) that provide maneuver and range day requirements. Most OSAF model instances include the eight range types with the highest weights in the ITC. Range requirements are expressed in range-days and maneuver land requirements expressed in kilometer-square-days. OSAF usually restricts the deviation between the required and available training assets. In so doing, it ensures that moving units do not increase training asset shortfalls. A subset of units can train at installations where they are not assigned.

#### OSAF Costs

OSAF typically minimizes the 20-year Net Present Value (NPV) of stationing a given force structure. Consistent with prior stationing analyses, OSAF considers both recurring and one-time costs. Recurring costs are further divided into fixed and variable costs.

*Fixed Costs:* Fixed costs are costs that occur regardless of the number of soldiers on an installation. The fixed cost includes fixed base operating costs for garrison activities and the minimum community facilities. Cost factors and relationships are from standard Army sources (for example, the Unit Relocation Cost Model and the Installation Status Report).

*Variable Costs:* Every unit stationed generates a variable cost for installation operations, imple-

--continued on page 36

#### About the INVESTIGATOR

**Robert F. Dell** is an Associate Professor in the Department of Operations Research. Dr. Dell completed his undergraduate studies, M.S. and Ph.D. in Industrial Engineering at the State University of New York at Buffalo. Dr. Dell joined the faculty of NPS in 1990.

Since 1990, he has taught and applied optimization to a variety of military problems. He has received research support from every uniformed service for topics ranging from program planning of ballistic missile defense to Coast Guard cutter scheduling. Various Army Base Realignment and Closure offices have continuously supported his research since 1990. He has also applied optimization in the private sector in areas ranging from production scheduling to supply chain design. His research appears in many open literature publications.

Dr. Dell is a member of the Institute for Operations Research and the Management Sciences (INFORMS) and Omega Rho. He is also an Associate Editor for *INTERFACES*.



**Robert F. Dell**

## FEATURED PROJECT

### SINKING A BODY USING BUBBLES

Associate Professor Bruce Denardo, Department of Physics

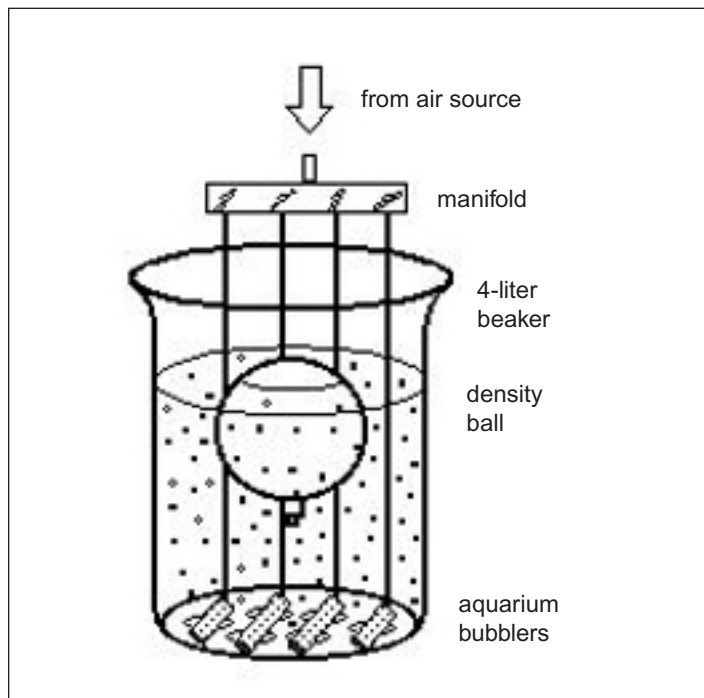
We recently published a technical journal article on the sinking of a floating body due to bubbles [1], which was the first scientific investigation of the physics of the phenomenon. Reports of our work appeared in the *New Scientist* magazine [2] and interviews have subsequently appeared in two television science documentaries. The attention was noticed by scientists who are now conducting investigations into the broad question of when bubbles cause a floating body to sink.

The main interest in this phenomenon is due to the idea that methane eruptions from the ocean floor may have caused the demise of some ships [3]. In fact, it is now suspected that this was responsible for a wreck at a methane pockmark called "Witches Hole" on the ocean floor [4]. The relevance of this for the Navy includes the possibility of a "buoyancy bomb," in which an underwater vehicle mines a methane hydrate deposit and later releases the gas to sink a floating target [5].

Work was initiated by the author in the mid-1990s, at the University of Mississippi. Physics class experiments were performed in which an ice cube was placed into a container of ethyl alcohol. By Archimedes' law, ice floats in water because the density of water is greater than that of ice. In the demonstration, however, the ice sank because the alcohol density was less than that of ice. A student came to me after class and asked what would happen if bubbles were added to water with ice floating in it.

The answer may appear to be obvious. If the average density of the bubbly water is less than the density of ice, then the ice should sink. However, this neglects a number of possible dynamic effects, one of which is that the rising bubbles can entrain an upward motion of the water which would then exert an upward drag force on the ice. The greater the amount of bubbles, the greater is the upward drag, so it may *not* be possible to sink ice or any other floating body! The impossibility of a ship sinking due to bubbles would be an interesting and important result.

An undergraduate student began working on an experiment to see if ice in water could be sunk with bubbles. He utilized aquarium bubblers and also decided to deal with a floating body whose average density could be readily and precisely varied. We chose a "density ball," which is a 10 cm diameter hollow stainless steel sphere with a removable plug. By adding or removing water from this body, ice became just one particular case. Figure 1 shows the simple apparatus. With it, we discovered that bubbles could indeed sink a floating body.



**Figure 1. Initial apparatus used to investigate the sinking of a body due to bubbles. The bubblers are held by suction cups to the bottom of the beaker. The ball has diameter of 10 cm.**

This is not surprising, but is not obvious due to a possible upward drag of the water.

Next, we decided to gather data for the average bubbly water density required to barely sink the ball, for different average densities of the ball. The main experimental difficulty in obtaining accurate and reproducible data was achieving a uniform flow of bubbles in the container. For a given ball density, our data showed that a somewhat smaller density of bubbly water was required to sink the ball. We thought that this could be due to an upward drag, but we were not sure. First, our method for determining the average density of the bubbly water was suspect. This was done indirectly by crudely measuring the bubble velocity and using the value of the air pressure. Second, the container was not much larger than the ball, so finite-size effects could be important.

In 1998 the author was at the Naval Postgraduate School, and again built a simple demonstration device

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## FEATURED PROJECT

### SINKING A BODY USING BUBBLES, *continued from page 6*

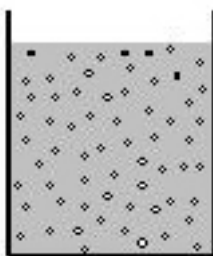
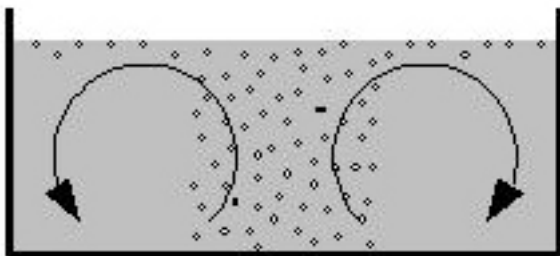
(Fig. 2). The bubbles are created when air is forced through many small holes drilled in a plastic plate that was glued near the bottom of a clear acrylic cylinder.

An essential distinction soon became clear. There are two special cases, as shown in Figure 3. Bubbles can fill the container (a *closed environment*), or can occupy a volume that is small compared to the container (an *open environment*). If the bubbles are uniformly distributed in the first case, the entrainment of water and thus an upward drag on a body, are expected to be negligible. However, due to the circulatory flow in the second case, there is expected to be a significant upward drag on a body in the bubble region. The ocean corresponds to the second case. As a result of our goal for obtaining accurate data, our experiment had evolved into the first case, which could rule out the effect that originally motivated our research! We recognized that our highly controlled experiment would just be an initial effort in the broad problem of the sinking of a body due to

*—continued on page 39*



**Figure 2.** Demonstration apparatus for sinking a body with bubbles, being operated at a section meeting of the American Association of Physics Teachers [6]. The volunteer is the daughter of a physics professor, and the author is controlling the valve.



**Figure 3.** Bubbles rising in a “closed environment” (left) and an “open environment” (far left). A steady flow of water is not expected in the first case if the bubbles are uniformly distributed, but is expected in the second.

### About the INVESTIGATOR

**Bruce Denardo** is an Associate Professor in the Department of Physics. Dr. Denardo received his graduate education from the University of California at Los Angeles, where he was a Regent's Fellow. He was awarded a Ph.D. degree in 1990. He was a postdoctoral fellow and then Assistant Research Professor in the Physics Department at the Naval Postgraduate School from 1990 to 1993, and an Assistant Professor of Physics at the University of Mississippi from 1993 to 1998. He returned to the Naval Postgraduate School faculty in 1998. He is a member of the Acoustical Society of America and the American Association of Physics Teachers. Dr. Denardo's areas of research include acoustics, nonlinear waves, fluid dynamics, and educational physics. He is currently investigating parametric excitation of high-intensity sound and active control of free-electron laser mirrors for use on ships. He is also writing a book on physics demonstrations. Professor Denardo is a dedicated teacher who encourages an active classroom environment with frequent demonstrations and connections with current scientific and technological progress.



**Bruce Denardo**



# RESEARCH CENTER

## UNDERSEA WARFARE RESEARCH CENTER REFLECTS RESEARCH FROM A VARIETY OF DISCIPLINES

The Undersea Warfare (USW) Research Center was established at the Naval Postgraduate School (NPS) in April 2002. The primary objectives of the USW Research Center are to: 1) provide outstanding support for U. S. Navy needs in USW education and research, and 2) make NPS a nationally recognized institution for USW education and research.

The USW Research Center expects to play a valuable role in support of the Navy Sea Power 21 concept and associated transformation capabilities. The appropriate focus will be in support of the Sea Shield portion of Sea Power 21. The Center will provide expertise and focused research efforts, in collaboration with Commander Third Fleet, which supports Sea Trial experimentation associated with Sea Shield capabilities and transformation. The Center will work closely with the USW Academic Committee by providing meaningful USW research opportunities to cement and transform the education skills acquired by NPS students into officer graduate capabilities that provide expert leadership in acquiring the Sea Shield transformation so vital to our Navy and national interests.

Another important component of Sea Power 21 is FORCENet. The USW Research Center will also contribute significantly to FORCENet. In a recent letter of appreciation from ADM James R. Hogg, USN (Ret.), Director of the CNO's Strategic Studies Group, he states, "Your insights in the area of acoustical communications were quite valuable

in conceiving the seabed-to-space multi-tiered sensor field in FORCENet. Your work demonstrates an excellent model for an underwater sensor field and wireless network, and helped answer some of the challenges of networking in such a difficult medium."

The Chair of Undersea Warfare, which was established by a Memorandum of Understanding between NPS and the Naval Undersea Warfare Center, will be dual-hatted as the Center Director. The USW Chair is expected to report in March 2002. The selection process is currently underway. The incumbent Chair of Mine Warfare (MIW), **RADM John D. Pearson, USN (Ret.)**, will be dual-hatted as the USW Center's Assistant Director, and is presently serving as the Center Interim Director. NPS faculty members of the Center are all involved in important USW research in submarine warfare, antisubmarine warfare, and/or mine warfare.

NPS USW research reflects a wide variety of NPS disciplines, including Operations Research, Physics, Electrical and Computer Engineering (Signal Processing), Oceanography, Mechanical Engineering (Robotics), and C4I (Common Undersea Picture and Underwater Communications/links to surface and above water nodes). The Center's research activities are supported by reimbursable research funding from external research sponsors.

*--continued on page 9*

### UNDERSEA WARFARE CENTER MEMBERSHIP

Associate Professor Steve Baker (Physics)  
Associate Professor Mary Batteen (Oceanography)  
Associate Professor Don Brutzman (Information Science)  
Professor Peter Chu (Oceanography)  
Professor Curt Collins (Oceanography)  
Professor Jim Eagle (Operations Research)  
Distinguished Professor Donald Gaver (Operations Research)  
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Professor Patricia Jacobs (Operations Research)  
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Professor Alan Washburn (Operations Research)  
Professor Larry Ziomek (Electrical and Computer Engineering)

# RESEARCH CENTER

## UNDERSEA WARFARE RESEARCH CENTER, *continued from page 8*

The USW Center provides three primary functions:

- Research Planning
  - Identification (internally and externally) of thesis topics, professors/advisors, and students,
  - Preparation of research proposals and coordination with potential external sponsors for funding of proposals,
  - Continuing solicitation, from external sponsors, of research topics of interest.
- Research Execution
  - Approve allocation and expenditure of funds for support of research programs,
  - Coordinate with principal investigators/faculty for execution of research programs,
  - Identify/propose solutions for problems encountered in the conduct of research programs.
- Research Database/Records
  - Bibliography of NPS USW research,
  - Bibliography of USW research documents produced outside NPS,
  - Bibliography of external sponsor research topics of interest.

*--continued on page 10*

## LINK BUDGET ANALYSIS FOR UNDERSEA ACOUSTIC SIGNALING

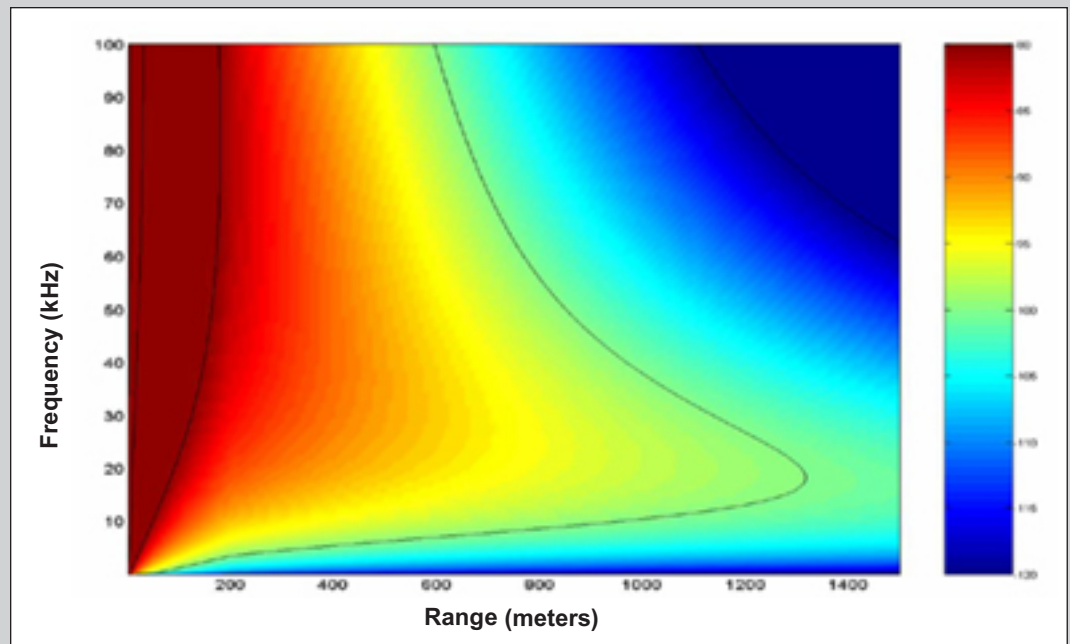
LT Joseph T. Hansen, United States Navy

Master of Science in Engineering Acoustics – June 2002

Advisors: Joseph A. Rice, Engineering Acoustics Chair, and Associate Professor Kevin B. Smith, Department of Physics

Link-budget analysis is commonly applied to satellite and wireless communications for estimating signal-to-noise ratio (SNR) at the receiver. Link-budget analysis considers transmitter power, transmitter antenna gain, channel losses, channel noise, and receiver antenna gain. For underwater signaling, the terms of the sonar equation readily translate

to a formulation of the link budget. However, the strong frequency dependence of underwater acoustic propagation requires special consideration, and is represented as an intermediate result called the channel SNR. The channel SNR includes ambient-noise and transmission-loss components. Several acoustic communication and navigation problems are addressed through wideband link-budget analyses.



Signal-to-noise ratio (SNR) of an undersea acoustic channel is strongly dependent on range and frequency as shown in this representative plot. Experimental Seaweb wide-area undersea networks for autonomous sensors and Unmanned Underwater Vehicles (UUVs) are using the 9-22 kHz band, and Seaweb local area networks will use the 30-100kHz band. Frequencies above 100kHz are useful for high-bandwidth acoustic data telemetry at short ranges.

# RESEARCH CENTER

## UNDERSEA WARFARE RESEARCH CENTER, *continued from page 9*

The USW Research Center is providing an integrated, comprehensive USW research program at NPS, based on strong leadership and USW credentials with significant, continuing value to USW research sponsors. This program provides a highly significant opportunity for meaningful thesis

work for NPS officer students. A complete bibliography of publications and research documents in these areas is available at <http://library.nps.navy.mil/home/bibs/submarine/> and <http://library.nps.navy.mil/home/bibs/seamines/>.

*--continued on page 11*

### HYDRODYNAMICS OF MINE IMPACT BURIAL

LCDR Ashley D. Evans, United States Navy

Master of Science in Meteorology and Physical Oceanography – September 2002

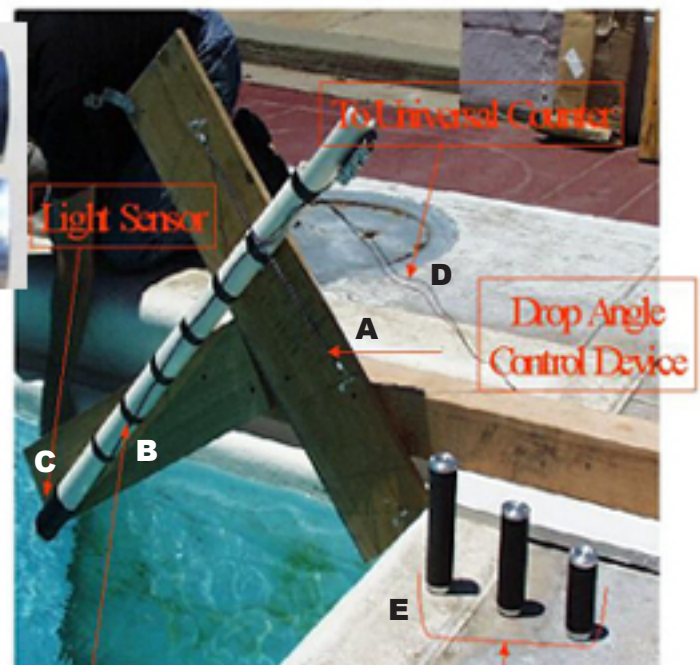
Advisors: Professor Peter C. Chu, Department of Oceanography, and Peter Fleischer, Naval Oceanographic Office, Stennis Space Center

A general physics based hydrodynamic flow model is developed that predicts the three-dimensional six degrees of freedom free fall time history of a circular cylinder through the water column to impact with an unspecified bottom. Accurate vertical impact velocity and impact angle parameters are required inputs to subsequent portions of any Impact Mine Burial Model. The model vertical impact velocity and impact angles are compared with experimental data, vertical impact velocities and impact angle to validate the model mechanics and accuracy. The three dimensional model results are compared through the experimental data with IMPACT28 vertical impact velocities and impact angle. Results indicate the three dimensional model mechanics are sound and marginal improvements are obtained in predicted vertical velocities. No improvement is gained using the three-

dimensional model over IMPACT28 to predict impact angle. The observed stochastic nature of mine movement in experimental data suggests this three dimensional model be used to model the hydrodynamic flow phase in a statistical mine burial model that provides distributions for input parameters and domain characteristics, and present a probabilistic output for development of a relevant navy tactical decision aid.



Equipment developed for the 1/15 scale mine drop experiment in the NPS swimming pool in July 2001. Here 'A' denotes drop angle device, 'B' is the mine injector, 'C' is the infrared light sensor, 'D' is output to the universal counter, and 'E' is mine shapes.



Mine Detector

Mine Shapes - Length: 15, 12, 9 cm  
Diameter: 4cm

# RESEARCH CENTER

## UNDERSEA WARFARE RESEARCH CENTER, *continued from page 10*

Recent theses of USW research of interest, in submarine warfare, antisubmarine warfare, and mine warfare include:

*The Influence of Shallow Water Variability on Short Range Water-Borne Propagation*, LT Stephen C. Karpi, USN (December 2002)

*Direct-sequence Spread-spectrum Modulation for Utility*

*Packet Transmission in Underwater Acoustic Communication Networks*, LCDR Peter S. Duke, Canadian Navy (September 2002)

*Link Budget Analysis for Undersea Acoustic Signaling*, LT Joseph T. Hansen, USN (June 2002)

*--continued on page 42*

## THE EFFECT OF SENSOR PERFORMANCE ON SAFE MINEFIELD TRANSIT

LT Chihoon Kim, Republic of Korea Navy

Master of Science in Operations Research – December 2002

Advisors: Research Associate Professor Steven E. Pilnick, Meyer Institute of Systems Engineering, Professor Patricia A. Jacobs, Department of Operations Research, and Distinguished Professor Donald P. Gaver, Department of Operations Research

Mines are relatively cheap weapons that can be employed in significant quantity by any country with even a modest military budget, and can be very effective at severely damaging or sinking ships or denying maritime access to an area. In this thesis, simulation and analytical models are formulated and studied to investigate the benefits and risks of mine avoidance, without object classification capability, under circumstances that include imperfect sensors and false targets. Two models of mine avoidance maneuvering are formulated, with increasing complexity in both their analytical and simulation implementations. With both formulations, results are obtained and analyzed to produce tables showing the probability of successful minefield transit as a function of sensor probability of detection vs. density of mine and non-mine, mine-like bottom objects, and the false alarm rate. The tables show the range of those parameter values for which mine avoidance maneuvering improves the probability of safe transit, and the values for which mine avoidance maneuvering reduces the probability of safe transit. The decrease is attributable to the fact that mine avoidance maneuvering increases the distance traveled in the minefield and the consequent risk of damage or destruction by an undetected mine. Quantitative results for the increased distance traveled in the minefield are also presented. Finally, a comparison of the two models of mine avoidance maneuvering show, not surprisingly, that the results of the simpler model are not good approximations of the results obtained with the more complex model, suggesting that even greater complexity in maneuver modeling may be desirable for some purposes.

**The Remote Mine-hunting System (RMS), under development by the Navy, is an example of a system that may be used for the tactics of mine-avoidance.**





## PSEUDOSPECTRAL METHODS FOR RAPID COMPUTATION OF OPTIMAL CONTROLS

Captain Jon D. Strizzi, United States Air Force

Doctor of Philosophy in Aeronautical and Astronautical Engineering – December 2002

Dissertation Supervisor: Associate Professor I. Michael Ross, Department of Aeronautics and Astronautics

Co-Advisor: Associate Professor Fariba Fahroo, Department of Applied Mathematics

Finding fast and accurate solutions to nonlinear optimal control problems has become increasingly important as our nation develops advanced space systems which require optimized maneuvers to be computed and executed in real time. In fact, much of the engineering design and performance analysis for these advanced systems can be formulated as optimal control problems. Examples are optimal trajectories for satellite launches (including launch-on-demand systems), orbit transfers, determining optimal spacecraft formations, satellite re-orientations, solar sail trajectories, flexible spacecraft slewing, and payload motion planning; with additional applications to advanced aeronautical maneuvers such as those for uninhabited combat air vehicles. These advanced

capabilities will require a real-time optimal control and guidance architecture, and this research investigates pseudospectral solution methods to provide rapid open-loop optimal controls as part of that architecture.

Several *practical* contributions are presented using an existing polynomial-based method for solving the discretized optimal control problem. A sparse computation approach is developed and employed on a PC platform, allowing easier use and reducing computation times by a factor of 60 for some problems. This new approach provides accurate numerical solutions and enhances the robustness of the existing pseudospectral method for some problem types. Novel itera-

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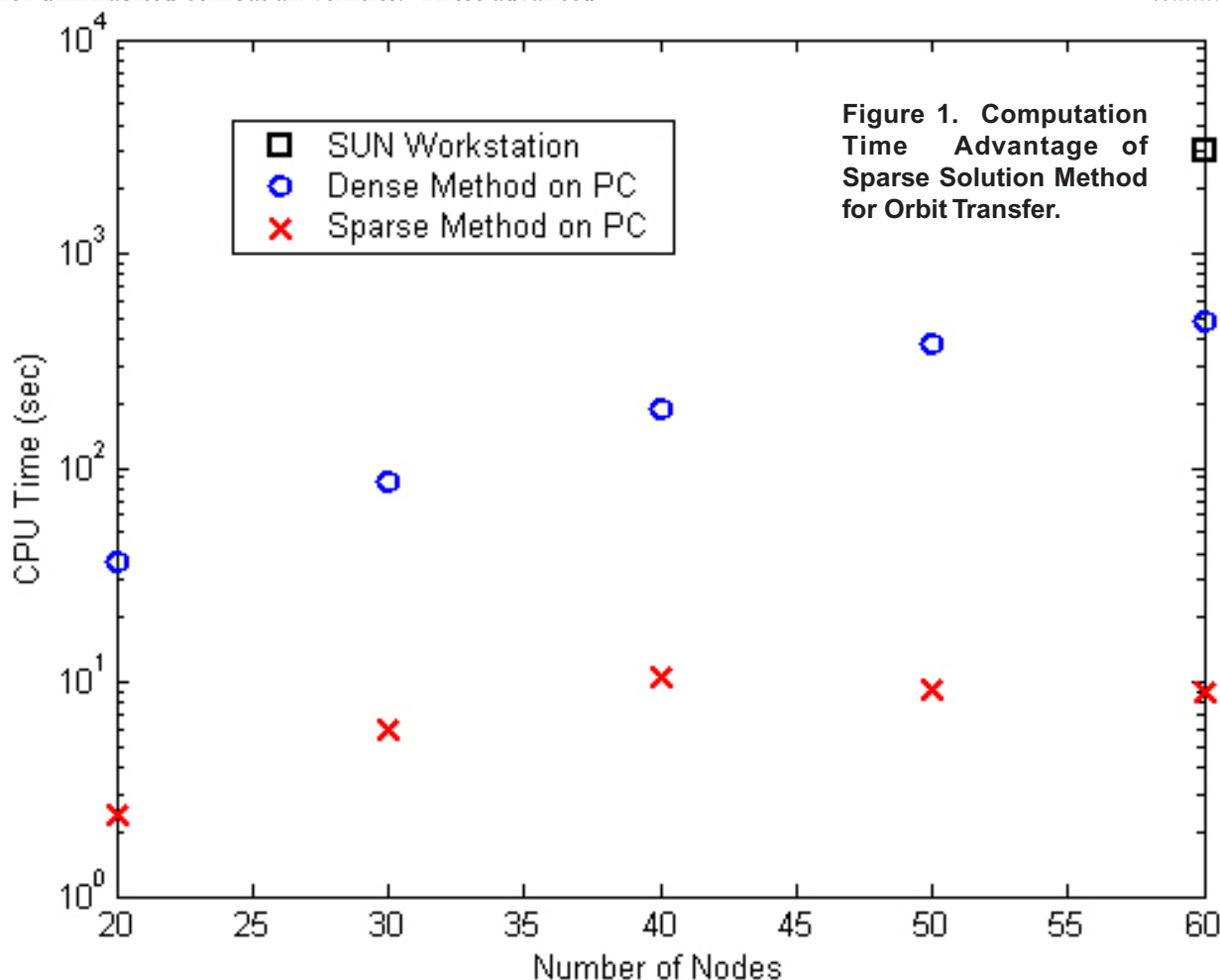
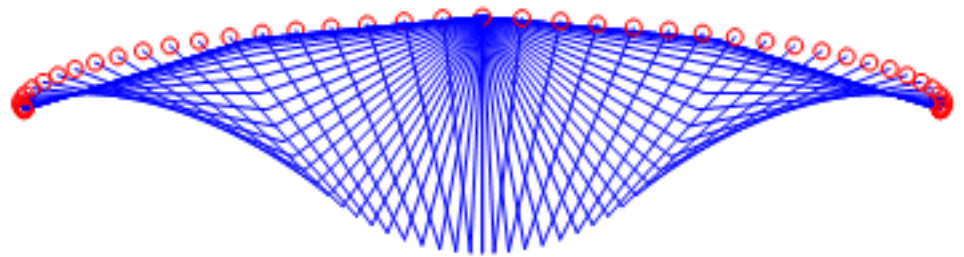


Figure 1. Computation Time Advantage of Sparse Solution Method for Orbit Transfer.

## METHODS FOR RAPID COMPUTATION OF OPTIMAL CONTROLS, *continued from page 12*

tive methods and the investigation of sparsity effects allow fast and accurate solutions for nonlinear problems. The first figure shows the computation time advantage of using a sparse solution method on a PC for a benchmark problem of maximizing an orbit transfer radius. The speedy nine seconds of CPU time contrasts starkly with the 50 minutes required on a SUN workstation prior to this research.

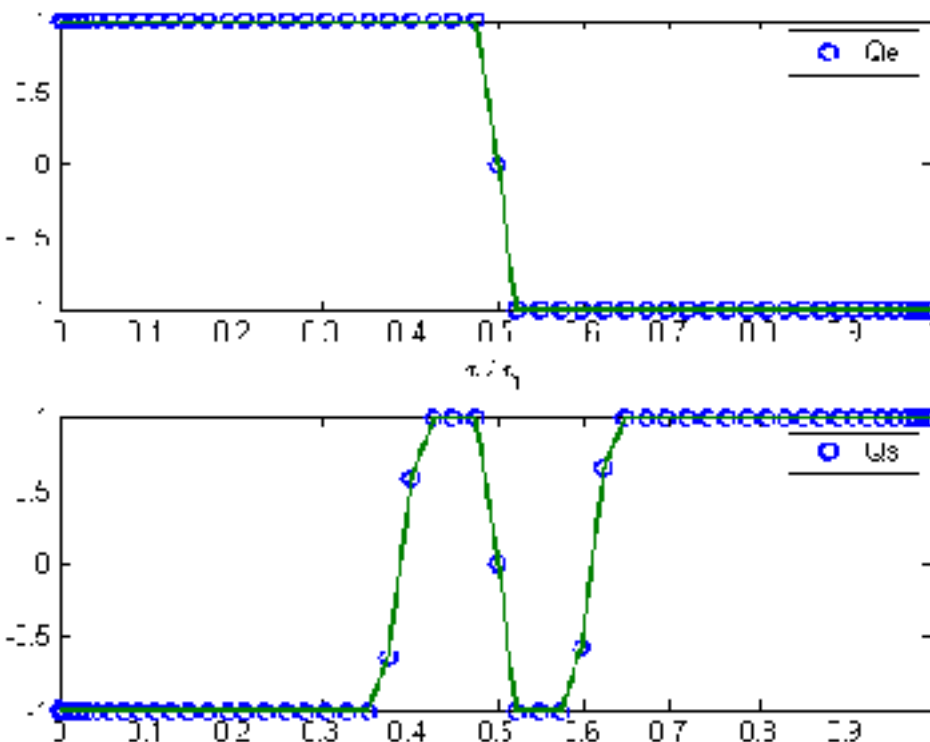
The *theoretical* contributions of the dissertation include the development of two new non-polynomial methods; one based on Sinc functions and the other using nonlinear domain transformations. Both new methods have the advantage of allowing adaptive grids, whereby the spacing of the discretization points is controlled by the user or may be determined optimally. This novel approach can reduce some computation times and converge to an optimal solution using fewer node points than the polynomial-based method with a fixed grid point distribution. The second and third figures show this method's solution for the minimum time pick-and-place motion of a segmented robot arm along with the switchings of the control torques between their maximum values.



**Figure 2. Minimum Time Path of Pick-and-Place Robot.**

The collection of these accomplishments results in a set of approaches, along with practical insights for each, to use pseudospectral solution methods for rapid computation of optimal controls. These methods can all take advantage of a sparse solution approach as demonstrated in this research. These contributions result in new pseudospectral solution methods to rapidly and accurately solve nonlinear optimal control problems for our nation's advanced aeronautical and astronomical systems. While these applications include low-thrust orbit maneuvers and vibration damping of slewed flexible spacecraft, there are also down-to-earth uses such as that of motion planning for industrial robots.

Captain Strizzi presented a portion of this research on sparse solution approaches at the American Institute for Aeronautics and Astronautics (AIAA) Guidance, Navigation and Control Conference in August 2002 in Monterey. The research on nonlinear domain mapping will appear within a larger effort by Professors Ross and Fahroo at the American Astronautical Society (AAS) Spaceflight Mechanics Meeting in February 2003 in Puerto Rico. Captain Strizzi graduated from NPS in December 2002, where this research assisted in his earning awards for outstanding U.S. Air Force student and academic excellence in space systems engineering. He is currently the Deputy Air Force Institute of Technology (AFIT) Liaison Officer at NPS and resides in the Guidance, Control and Optimization Laboratory in the Department of Aeronautics and Astronautics.



**Figure 3. Time-Optimal Control Torques for Robot Arm.**

## STUDENT RESEARCH

### MEGAWATT CLASS FREE ELECTRON LASERS FOR NAVAL APPLICATION – SHORT RAYLEIGH LENGTH AND STABILITY ANALYSIS

LT William J. Ossenfort Jr., United States Navy

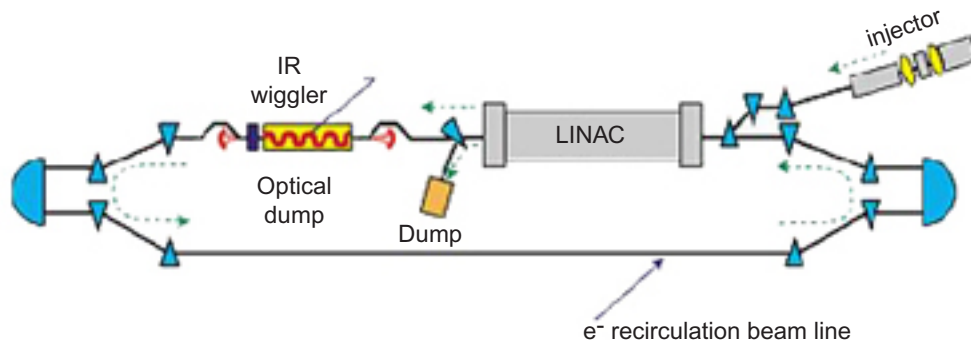
Master of Science in Physics – December 2002

Advisors: Distinguished Professor William B. Colson and Associate Professor Robert L. Armstead, Department of Physics

The free electron laser (FEL) is theoretically capable of scaling up to a MW class laser for naval point defense. At such high power levels, the FEL's optics could be damaged.

An FEL operating with a short Rayleigh length reduces intensity at the mirrors; however, the performance of short Rayleigh length FELs is unknown. This thesis presents simulations of Thomas Jefferson Laboratories' proposed 100

kW FEL operating with a short Rayleigh length, and of a proposed 1 MW FEL undergoing shipboard induced mirror vibrations. In the 100 kW FEL, Rayleigh lengths of  $0.1L$  to  $0.5L$  (where  $L$  is the undulator length) were simulated.



**Schematic of the Thomas Jefferson Lab FEL, a Prototype for a High Average Power Directed Energy Weapon for Ship Defense.**

Weak field gain increases as Rayleigh length decreases, indicating that short Rayleigh length FELs will start from spontaneous emissions. Final FEL efficiency also increases as Rayleigh

length decreases, with the exception of a spike at the typical Rayleigh length design value of  $0.3L$ . For the 1 MW FEL system, the high operating current acts to stabilize the optical mode against

vibrations that result in mirror tilts of 0 to 400 microradians, where final output power was reduced 80%. When used in conjunction with an active mirror alignment system, output power of the 1 MW FEL is unaffected.

### BUDGET PREPARATION, EXECUTION AND METHODS AT THE MAJOR CLAIMANT/BUDGET SUBMISSION OFFICE LEVEL

CDR James E. Reed, United States Navy

Master of Science in Management – December 2002

Advisors: Professor Jerry L. McCaffery and Senior Lecturer John E. Mutty, Graduate School of Business and Public Policy

This thesis describes the current Planning, Programming, and Budgeting System (PPBS) process at a Navy Major Claimant/Budget Submitting Office (BSO) by examining the overall navy processes and the process employed at a major claimant/BSO, COMPACFLT (CPF). A description is provided of the scope of the Planning, Programming, and Budgeting requirements at CPF by explaining its Area of Responsibility (AOR) and the major sub-claimants who rely on CPF for program and budget submissions and subsequent allocation of resources. The thesis then describes the current Navy PPBS process, the process at CPF, and the interactions that occur between the two. Next, the thesis describes and analyzes the concurrent program/budget pro-

cess implemented by the Secretary of Defense in August 2001 and the perceptions among CPF staff for the reasoning behind the change. The differences in funding between readiness accounts that directly support operating forces and support accounts that provide resources to the infrastructure account that supports those forces are examined. Finally, the intricate, yet reiterative nature of the process and the informal PPBS process that occurs between participants on a day-to-day basis is discussed. This thesis was prepared by reviewing current documentation of the PPBS process and by conducting interviews with key members of the CPF planning, programming and budgeting staffs.

# STUDENT RESEARCH

## ASSESSING THE RISK OF INADVERTENT NUCLEAR WAR BETWEEN INDIA AND PAKISTAN

MAJ Stephen A. Smith, United States Army

Master of Arts in National Security Affairs – December 2002

Advisor: Assistant Professor Peter R. Lavoy, Department of National Security Affairs

Conventional warfare between India and Pakistan could inadvertently escalate to nuclear warfare. Asymmetries in military doctrine and capability undermine deterrence stability and could lead to the use of nuclear weapons if the two nations become engaged in a large-scale conventional conflict. Following the 1998 nuclear weapons test, the 1999 Kargil Conflict played out under the nuclear umbrella, but remained very limited. However, there is a growing gap in conventional military capabilities, and growing pressure in India to retaliate against Pakistan for its alleged support of terrorism and insurgency. India has invested heavily in force modernization, potentially changing the scope of conventional military operations and leading to Pakistan's inadvertent use of nuclear weapons. This thesis examines the possibility of inadvertent nuclear escalation between India and Pakistan. It analyzes the deterrence system that is evolving in South Asia, and describes the conditions under which the system could fail. Large-scale conventional war could threaten the survival of strategic forces, or threaten vital strategic command and control functions. Finally, Pakistan could adopt a launch-on-warning posture to guard against an Indian pre-emptive attack. This thesis concludes by recommending steps that the United States could take to ensure peace and decrease destabilizing factors in the region.

## TRACKING CONTROL OF AUTONOMOUS UNDERWATER VEHICLES

LT Joseph J. Keller, United States Navy

Mechanical Engineer – December 2002

Master of Science in Mechanical Engineering – December 2002

Advisor: Professor Anthony J. Healey, Department of Mechanical Engineering

Recovery of Autonomous Underwater Vehicles (AUVs) can often be an autonomous operation itself. In the case of an AUV that is launched and recovered at some significant depth below the surface, the recovery platform to which the vehicle will dock is often not a stationary platform. The recovery cage/platform has dynamics associated with it which are induced by wave motion effects on the ship to which the cage is tethered. In order to successfully recover a vehicle into a cage platform it will be preferred for the vehicle to have the capability to compensate for this motion when making its final approach to the cage. Using active compensation, a smaller cage can be utilized for recovery of an AUV.

This research attempts to investigate a means by which a vehicle may be made to track, in depth, dynamic motion with zero phase lag between the vehicle and the recovery platform utilizing an error space controller.

## A CONTRACTOR LOGISTICS SUPPORT ACQUISITION DECISION SUPPORT MODEL

LCDR Richard K. McCarthy, United States Navy

Master of Science in Management – December 2002

Advisors: Senior Lecturer Don Eaton and Associate Professor David V. Lamm, Graduate School of Business and Public Policy

Decreased military budgets mean that aircraft recapitalization occurs only where savings and cost cutting can be realized and funds redirected into new acquisitions. The primary area of cost cutting is lifecycle support costs, and the Department of Defense continues to pioneer logistics support concepts in efforts to reduce these costs. We need to ensure that new logistics support strategies are implemented using sound methodology so that actual savings are realized without sacrificing readiness. Without realizing savings and understanding what performance metrics we desire (e.g. operational readiness), we can actually be infusing greater costs into our acquisitions of long-term logistics support.

This thesis examines the Navy's experience with Contractor Logistics Support (CLS) using the F/A-18 E/F Integrated Readiness Team (FIRST) Program as a case study. The goal of this research is to review our policies, understand the issues, and analyze our decision making process for awarding CLS contracts. The results suggest that current decision analysis is not well documented and does not consider all of the significant variables. By considering these additional variables, a decision support model is developed to assist in making more sound judgments regarding outsourcing logistics.



# STUDENT RESEARCH

## PROMPT DOSE RADIATION EFFECTS IN SOI N-CHANNEL MOSFETS

LCDR Carlos J. Carroll, United States Navy

Master of Science in Electrical Engineering – December 2002

Advisors: Associate Professors Todd R. Weatherford and Sherif Michael, Department of Electrical and Computer Engineering

This thesis investigates observed anomalous total dose effects in Silicon-on-insulator N-MOSFET devices following exposure to a prompt radiation dose (prompt dose effects) not observed during low dose rate testing. Previous radiation hardness testing on 4 kbyte ferroelectric memory chips with SOI CMOS read/write circuitry, showed a disparity in post-exposure characteristics between low dose rate Co-60 testing and high dose rate (prompt dose) linear accelerator testing. At high bias voltages, prompt dose exposures resulted in significantly lower failure threshold doses, increased leakage currents at lower doses and subsequent annealing which was not observed in the low dose exposures. By recreating the linear accelerator testing at the device level, using the radiation test facilities at the Naval Postgraduate School, and focusing on the post-exposure leakage currents, an attempt was made to observe and further characterize the annealing effects following prompt dose exposure. Edgeless and multi-edged transistor topologies were used to help localize to the source of the leakage currents. Though no anomalous prompt dose effects were observed, disparities between low dose rate Cobalt-60 test results and the NPS LINAC results were evident. Probable causes for these disparities, as well as further testing, are proposed.

## A COMPACT AND INEXPENSIVE HYDROPHONE HAVING ULTRA LOW SELF-NOISE

LT Stavros Polydorou, Hellenic Navy

Master of Science in Applied Physics – December 2002

Master of Science in Engineering Acoustics – December 2002

Advisors: Associate Professor Thomas Hofter and Research Professor Thomas Muir, Department of Physics

A hydrophone has been constructed and tested with the following characteristics. Two thick piezoceramic (PZT) disks are combined in simple can-shaped aluminum housing. The geometry provides for acoustic pressure amplification and provides a small amount of internal space for a tiny low noise preamp. The resulting device has a size of 3 cm, a high acoustic sensitivity, flat frequency response from 3 Hz to 10 kHz, and self-noise well below Knudsen sea-state-zero over the specified frequency range. The total parts cost is roughly \$25 for parts purchased in small quantities. The cost of labor, machining, cables and encapsulants is not included.



## IN MEMORY

Commander William C. McCool  
United States Navy  
1961-2003

Master of Science in  
Aeronautical Engineering  
Naval Postgraduate School  
1992

## USNA FEATURE

### UNITED STATES NAVAL ACADEMY MIDSHIPMEN TO PRESENT AT THE NATIONAL COUNCIL ON UNDERGRADUATE RESEARCH

United States Naval Academy (USNA) students are encouraged to become more involved in hands-on, open-ended research projects. In a given semester approximately thirty-five midshipmen elect to conduct independent research projects under the mentorship of USNA faculty.

Five students currently involved in research projects have submitted their abstracts to a competitive review board for the National Council on Undergraduate Research (NCUR). The abstracts have been accepted and the students, Midshipmen First Class Peter Buryk, Tyler Churchill, Matthew Isenhower, Benjamin Visger, and Midshipman Third Class Sean Jones, will present at the NCUR annual meeting in Salt Lake City in March. The successful abstracts are featured below.

### COMPUTATIONAL APPLIED MATHEMATICS AND THE N-BODY PROBLEM

Midshipman Third Class Sean Jones, Computer Science Major

Advisor: Professor Reza Malek-Madani, Department of Mathematics



Midshipman Third Class Sean Jones with advisor, Professor Reza Malek-Madani.

In this talk I will present a numerical study of the N-Body problem. This problem requires solving a large system of non-linear ordinary differential equations, where the nonlinearity is due to a potential function that measures the interaction force among the particles.

The main aspect of my research focused on solving the initial-value problem by designing a parallel algorithm suitable for implementation on a Beowulf Cluster, a collection of COTS (Commercial-Off-The-Shelf) machines connected using a network and utilizing the Linux operating system. The tests were run on the Naval Academy's Armada cluster of 16 AMD Athlon processors with a Fast Ethernet interconnect using the Scyld Beowulf Linux Distribution.

In addition to describing the physics of the N-Body problem and a short summary of the architecture of the Cluster, I will address computational performance issues of our algorithm including Amdahl's law implications and scheduling.

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### SUPRAMOLECULAR COMPLEXATION OF A MEROCYANINE DYE BY AMYLOSE

Midshipman First Class Benjamin Visger, Chemistry Major

Advisor: Associate Professor William Heuer, Department of Chemistry

Under certain conditions, amylose (a purified form of starch) forms helical structures capable of supramolecular ("host-guest") complexation of hydrophobic molecules. The formation and spectroscopic properties of such complexes with several dipolar organic chromophore dyes has been studied. A merocyanine dye with a 16-carbon alkane "tail" is synthesized and its absorption and fluorescence spectra are recorded in various DMSO/water mixtures, both in the presence and absence of amylose. Formation of the supramolecular complex is signaled by changes in the spectral properties of the dye. Dramatic red-shifting of the emission band of the dye upon complexation occurs due to selective stabilization of the excited state by the hydrophobic interior of the amylose helix. The extent of complex formation is found to depend strongly on both the

*--continued on page 18*

### INVESTIGATION OF TELLURIUM-130 NUCLEAR STRUCTURE USING INELASTIC NEUTRON SCATTERING

Midshipman First Class Tyler Churchill, Physics Major  
Advisor: Professor Jeffrey Vanhoy, Department of Physics

This project is an investigation of the nuclear structure of Tellurium-130. The purpose of nuclear structure research is to understand the features of nuclear force that determine the balance between the various ways a nucleus can behave. Theoretical model calculations are compared to experimental data to understand which models work better under which circumstances. Experimental data have been taken at the University of Nuclear Structure Laboratory using a technique called inelastic neutron scattering. By scattering neutrons off of Te-130, the nucleus can be excited, and the resulting de-excitation gamma rays recorded as the Te-130 excited states relax. Through various analytical techniques, the energy level scheme will be constructed, and spectroscopic information such as lifetimes, level spins and parities, and decay branching ratios will be extracted. The behavior of the  $^{130}\text{Te}$  nucleus will be examined from the viewpoints of the Interacting Boson Model-2, the General Collective Model, and the Particle-Vibrational Model. Emphasis centers on understanding the interplay between particle and collective features and on the aspects of the nuclear forces and shell model orbitals that determine the relative importance of each model.



Midshipman First Class Tyler Churchill with advisor, Professor Jeffrey Vanhoy.

### SUPRAMOLECULAR COMPLEXATION OF A MEROCYANINE DYE, *continued from page 17*



composition of the solvent mixture and the pH. The acid-base properties of the amylose-merocyanine inclusion complexes are studied in detail using spectrochemical titrations. The results of these studies are compared to results obtained using a hemicyanine dye guest, which does not have acid-base properties. Thin films of such amylose-dye complexes may be useful as solvent polarity indicators, molecular sensors and non-linear optical materials.

Midshipman First Class Benjamin Visger with advisor, Associate Professor William Heuer.



## USNA FEATURE

### EXPLORING THE IMPACT OF POLITICAL EXPERIENCE ON COMPETITIVE CONGRESSIONAL ELECTIONS

Midshipman First Class Matthew Isenhower, Political Science Major

Advisor: Professor Steven Frantzich and Assistant Professor Howard Ernst, Department of Political Science

This study examined whether certain political experiences give a congressional candidate a greater advantage in open seat races and elections in which an incumbent was unseated. An empirical database of the 313 candidates in these types of races for the 1996, 1998, and 2000 general election was created. Variables collected include prior experience as a congressional staffer, prior elected political office and candidate demographic information. This data was analyzed utilizing a three-stage process: correlations, cross tabulation with limited controls, and multivariate regression analysis. Results include frequency distribution, cross tabular and regression statistics as a function of the independent variables of money raised, percentage of both overall and two-party votes won, and whether a candidate won his or her election. This study tests two general hypotheses. First, those candidates with prior political experiences will demonstrate strategic behavior and will be elected more often than candidates without comparable political experiences. Second, prior staffers and prior elected officials will



Midshipman First Class Matthew Isenhower with advisors, Professor Steven Frantzich and Assistant Professor Howard Ernst.

receive a higher percentage of the vote and raise greater amounts of money relative to their opponents. Results support the study's hypotheses and further understanding of the factors that have the greatest influence on congressional elections.

### CHICAGO'S PRAIRIE CLUB AND PATTERNS IN AMERICAN ENVIRONMENTAL HISTORY

Midshipman First Class Peter Buryk, History Major

Advisor: Professor David Peeler, Department of History

This is a historical project examining the origins and growth of a Midwestern environmental group, exploring issues and circumstances that would go on to characterize patterns of development in twentieth century American environmentalism

The Prairie Club of Illinois was founded in order to "teach the throngs of the city the romance of common things" and "give to others the joy of the great out-of-doors".<sup>1</sup> This progressively minded mission set the foundation for an organization committed to outdoor recreation, fellowship, and conservation. The Chicago-based Club prided itself on organizing and leading weekend hiking trips to the Lake Michigan Dunes of northern Indiana and southwestern Michigan. From its creation in 1898 until its maturity in 1930,

*--continued on page 41*



Midshipman First Class Peter Buryk with advisor, Professor David Peeler.



# PROJECT NOTES

## NAVAL POSTGRADUATE SCHOOL PARTNERS WITH UNIVERSITY OF CALIFORNIA-SANTA CRUZ TO SUPPORT CENTER FOR INTEGRATED MARINE TECHNOLOGY

NPS faculty and technical staff from the Department of Oceanography are participating in a new, NOAA-sponsored program to develop and link marine observing systems around Monterey Bay. The program, which is centered at the University of California, Santa Cruz, is known as the Center for Integrated Marine Technology (CIMT). **Associate Professor Jeffrey Paduan**, who is the CIMT co-director, and **Associate Research Professor Leslie Rosenfeld** are playing the lead roles in helping to bring real-time measurements of the physical environment, including ocean currents, temperatures, and salinities, to the Center in support of the larger goals of monitoring and under-

standing the upwelling ecosystem off our coastline. A recent multi-institutional program called the Innovative Coastal-Ocean Observing Network (ICON) was centered at NPS and helped to build the observing infrastructure that will become the backbone of CIMT. Those observations include surface current maps from a network of high frequency (HF) radar sites along the shoreline and vertical profiles of currents and temperatures from a number of moored platforms out in the Bay. The new Center will link these physical observations with ongoing bio-chemical data from research cruises using new database and visualization technologies.

## FATIGUE AND HUMAN PERFORMANCE

Associate Professor Nita L. Miller, Department of Operations Research

Research Assistant Professor Jeffrey Crowson, Department of Operations Research

Due to the tremendous demands that have been made on our military forces since 9/11, fatigue and sleep deprivation have become important to our national security interests. Fatigue research being conducted by the Naval Postgraduate School is making an impact in the U.S Navy. **Associate Professor Nita Miller**, a faculty member in the Departments of Operations Research and Systems Engineering, has been in the forefront of the Navy's efforts to address fatigue in our military troops. Her students have collected sleep and fatigue data during combat on the *USS STENNIS* and at the Naval Training Center at Great Lakes, Illinois. Other students have conducted sleep surveys of Navy submariners. Her efforts have taken her to Fleet Battle Exercise Juliet and aboard the *HSV Joint Venture* where she has documented the tremendous impact of sleep deprivation and reduced manning issues. Dr. Miller has been invited to collect data on sailors aboard the *USS CONSITUTION*, currently on cruise in the Persian Gulf. Additionally, Dr. Miller consults with the NPS Center for Executive Education where she offers senior military participants the chance to observe their own sleep patterns. Several of the recent master's theses completed by her students are described below.

Navy **LT John Nguyen's** thesis explored the effects of reversing the work-sleep schedules of the crew aboard the *USS JOHN C. STENNIS* during combat operations against Afghanistan. It also reviewed current research in the field of sleep deprivation and the resulting performance decrements in humans. The results of the study indicated that a significant number of sailors had difficulty adjusting to working

nights and sleeping days. Additionally, this study found that individuals working topside have greater difficulty adjusting to the reversed schedule than do their counterparts who work below decks. Using a validated model of human performance and fatigue, it was found that the level of fatigue and sleep deprivation observed in crewmembers lead to significantly reduced individual effectiveness. Recommendations addressed the need for educating military personnel on the subject of fatigue and sleep logistics, the importance of fatigue countermeasures, and the need for further research on this topic.

**LT Brian Baldus'** thesis investigated the sleep patterns of recruits at the U.S. Navy Recruit Training Command in Great Lakes, Illinois, which is responsible for training all enlisted personnel, about 50,000 young recruits per year. Demands on these recruits are steep and there was concern that by restricting the amount of sleep, learning efficiency may be adversely affected. There were additional concerns about possible increases in attrition and reductions in morale due to sleep deprivation. Every minute of the 63-day training schedule is closely managed, including the time allocated for sleep. In recent years, the designated sleep regimens have changed considerably from six hours of sleep (2200 to 0400) in 2001 to eight hours of sleep (2200 to 0600) as of June 2002. In the months of April through June 2002, data was collected on the *quantity* and *quality* of sleep received by 31 volunteer recruits in two eight-hour conditions: 2100 to 0500 and 2200 to 0600. Using wrist activity monitors, calculations

--continued on page 21

# PROJECT NOTES

## FATIGUE AND HUMAN PERFORMANCE, *continued from page 20*

were made of the *actual* amount of sleep per person and contrasted it with the *expected* amount for each participant. Additionally, comparisons were made between bedtimes (2100 vs. 2200), gender, different training divisions, nights with and without sleep disruptions (due to watch standing and other factors), and different days of the week.

LCDR Donnie Gamboa's thesis examined the reported sleep patterns among a sample of U.S. Navy Submarine Force enlisted personnel, and made an initial assessment of their perception of their sleep allowances at sea and ashore. The goal of this research was to determine if a shift in working environment from shore duty (baseline) to the arduous environment of sea duty (underway) had an effect on the sleep patterns of enlisted submariners. Additionally, any effects of career longevity and "optimal sleep duration" (self-reported)

were also investigated. This thesis also included a review and discussion of salient research in sleep deprivation and cognitive dissonance reduction theory, and attempted to address the idea that cognitions/attitudes change to accommodate behavior or the external environment, perhaps by presenting an explanation for those sleep patterns.

A current research project is underway in collaboration

*--continued on page 22*



**Due to the tremendous demands that have been made on our military forces since 9/11, understanding fatigue and sleep deprivation, and how to prevent them, have become important to our national interests.**



## RELATIONSHIPS

### NAVAL POSTGRADUATE SCHOOL-THIRD FLEET DESK ALLOWS FOR CLOSE INTERACTION WITH THE FLEET

The Naval Postgraduate School (NPS), working with VADM Bucchi, Commander, Third Fleet (C3F), has established a C3F-NPS "Desk" on the *USS Coronado*, Flagship of the Third Fleet in San Diego. The primary purposes of the desk are to: 1) provide innovative ideas and knowledge of current emerging technologies of value to the Fleet/Sea Based Battle Lab, and 2) increase faculty awareness of Fleet operations and needs. It is also an opportunity for faculty to obtain data in support of their existing research programs and/or to obtain knowledge and verbal support from the Fleet for future proposals to Navy commands.

Professor Alan Washburn of the Department of Operations Research has just returned from a three-month tour as the NPS Desk at Third Fleet in San Diego. Most of his time was spent on board *USS CORONADO*, VADM Bucchi's flagship, including two weeks at sea.

Professor Washburn arrived in October, just in time to participate in ASWEX 03-1, an antisubmarine warfare (ASW) exercise in the southern California (SOCAL) area off San Diego. He rode aboard the *USS CONSTELLATION* throughout, spending most of his time in the ASW cell, watching the management of the ASW campaign against two

simulated diesel submarines. After the exercise, he helped the Center for Naval Analyses reconstruct what had actually happened. There is a great deal of concern about ASW in the Navy right now, and Washburn's experience has led him to share it. "The lack of recent funding for ASW is quite apparent," he said, "especially in the area of Tactical Decision Aids." He adds that the *CONSTELLATION* battle group nonetheless did amazingly well, given the communication difficulties and lack of computerized decision aids.

ASWEX 03-1 was preparatory to the Joint Task Force exercise (JTTFEX) that every battle group carries out before deploying (the *CONSTELLATION* battle group is now deployed in the Arabian Sea). Washburn joined *CORONADO* for the rest of the JTTFEX, monitoring the process that produces Air Tasking Orders (ATO). These are the orders that apportion tasks to aircraft over a moving time horizon. Washburn is convinced that the ATO generation process could also benefit from additional computerized decision aids, in this case based on LtCol Kirk Yost's 1998 PhD dissertation. "The whole process," he says, "could probably be encompassed in one large but solvable joint optimization scheme." Attempts to

--continued on page 23

### FATIGUE AND HUMAN PERFORMANCE, *continued from page 21*

with the Navy Submarine Medical Research Laboratory (NSMRL) in New London, CT. The objective of this study will be to gain insight into the sleeping patterns of U.S. Navy personnel during various watchstanding shifts aboard an U.S. Navy submarine while underway. The Navy is particularly interested in determining if altering underway watchstanding will significantly impact the ability of crewmen to perform their duties. This study will attempt to quantify these factors in an empirical manner. The reported fatigue and sleep quality of the crew will be assessed to determine if their off-duty time is adequate for sufficient rest. The project will use small wrist activity monitors similar to those used in the projects completed by LT Nguyen and LT Baldus.

Although similar studies have been performed on U.S. Navy personnel during watchstanding aboard surface vessels, no study to date has assessed the sleep quality

and performance of watchstanders aboard a U.S. Navy submarine. At the completion of the study, the activity monitors will be returned to NPS for data analysis. Based on the analysis of actigraphy data and other performance measures and questionnaires that are collected, this study will attempt to determine if there are demonstrable differences in human performance that are attributable to various watchstanding schedules.

The Operations Research Department at NPS has established a new curriculum in Human Systems Integration (HSI). This curriculum will lead to a Master of Applied Science degree. The new track will offer students an opportunity to gain both theoretical and applied experience in the field of human systems integration. Human Systems Integration emphasizes human considerations as a top priority in the process of systems acquisition in order to optimize life cycle costs and system performance.

## RELATIONSHIPS

### NAVAL POSTGRADUATE SCHOOL-THIRD FLEET DESK, *continued from page 22*

convince others of this are ongoing.

Washburn offered to teach a non-credit, nine-hour short course called "Navy Probability," and Third Fleet took him up on it. The class took place on three days in early December while *CORONADO* was at sea. Enrollment consisted of 18 students, including five enlisted. The course emphasized the importance of Probability concepts such as "experiment" and "event" as much as computations. The Flag Briefing Room, with its generous computer support, doubled quite well as a classroom. The only hard thing about teaching at sea, according to Washburn, was that *CORONADO* would occasionally roll enough to make his keyboarding attempts somewhere between comic and impossible!

In getting acclimated to how things are actually supposed to happen in Naval warfare, Washburn had numerous occa-

sions to consult Naval Tactical Training Publications (NTTP, renamed from NWP). He came away convinced that the NTTP series could be improved by taking advantage of hypertext. Most NTTPs are currently distributed over the web or by compact disk, as pdf files. Hypertext would make them easier to read and much more effective training documents, Washburn thinks, and would also permit taking advantage of the computational capability that is now widely distributed in the fleet. In particular, there could be opportunities for NPS students to write theses that take the form of an embedded computational capability, possibly based on Excel spreadsheets. In conjunction with Third Fleet and the Naval Warfare Development Command Chair for Warfare Innovation, CAPT Jeff Kline, USN, Washburn plans to continue pursuit of this goal.





## CHAIR PROFESSORSHIPS

### CHAIR PROFESSORSHIP IN HONOR OF ADMIRAL JEREMY MICHAEL BOORDA HAS BEEN REDEFINED

A Memorandum of Understanding (MOU) between the Naval Postgraduate School (NPS) and the Chief of Naval Personnel (CNP) redefined the Chair Professorship in honor of the late Admiral Jeremy Michael Boorda. The MOU establishes a Chair Professorship in Manpower, Human Resources Management, and Leadership. The Chair is located in the Graduate School of Business and Public Policy (GSBPP).

The object of the professorship is to provide a direct relationship between CNP and NPS and to accomplish the following: 1) act as the primary NPS contact for leadership, manpower, and human resource management issues; 2) facilitate discussion of issues related to the Manpower Systems Analysis curriculum and the bi-annual curriculum review process; 3) provide direct NPS support for the development of future leadership of the 1200 community; 4) facilitate research supportive of CNP requirements; and, 5) facilitate opportunities for professional development of both faculty and students in the Manpower Systems Analysis curriculum at NPS. The specific research objective is to stimulate current research in topics of immediate concern to CNP and to enhance research conducted by NPS faculty and student. The specific educational objective is to enhance the capabilities of graduates to assume Manpower and policy-making positions within the Department of the Navy.

The current "Boorda Chair" Professor is **RADM David S. Bill, III, USN (Ret.)**. RADM Bill is the son of a career naval officer. He graduated from the U.S. Naval Academy and holds a degree in Ordnance Engineering from NPS. He also attended the Royal Naval Staff College in Greenwich, England.

His early duty assignments include Gunnery Officer and Anti-Submarine Officer on the *USS JOHN KING* (DD G3), Weapons Officer on the *USS J.P. KENNEDY* (DD 850), Operations Officer aboard the *USS TALBOT* (FFG4) and Executive Officer of *USS COONTZ*. After serving in Vietnam, assignments included the Naval Forces Caribbean and U.S. Naval Forces Europe. Admiral Bill has commanded the *USS MAHAN* (DDG 42), *USS MOBILE BAY* (CG 53), *USS WISCONSIN* (during Desert Shield and Desert Storm), and Commander Cruiser Destroyer Group 12, *ENTERPRISE* Battle Group. Staff assignments include Director of the Sur-



**RADM David S. Bill, III, USN (Ret.), the Admiral Jeremy Michael Boorda Chair of Manpower, Human Resource Management, and Leadership in the Graduate School of Business and Public Policy at the Naval Postgraduate School.**

face Ship and Combat Systems Branch of the Chief of Naval Operations, Director for Operations Plans and Policy and Chief of Staff, U.S. Atlantic Fleet, and Deputy Commander in Chief, U.S. Naval Forces Europe. He retired from active duty after thirty-two years of service in 1998.

As the Boorda Chair, Admiral Bill has formulated a busy agenda. His goals in the coming year include: 1) assisting in creating a continuum of educational development for the Human Resources Management Community; 2) obtaining sponsorship of the Personnel Management Curriculum from the Surgeon General, U.S. Naval Academy and Headquarters, U.S. Marine Corps; 3) generating research topics from the Chief of Naval Personnel that address Navy personnel management issues; 4) establishing a liaison position in Washington to help initiate the Joint MBA Program; 5) establishing an industry-sponsored chair in GSBPP; and, 6) developing close industry relationships and partnerships.

# AGREEMENTS

## **BATTLESPACE ENVIRONMENTS CHAIR PROFESSORSHIP ESTABLISHED AT THE NAVAL POSTGRADUATE SCHOOL**

A Memorandum of Understanding between the Oceanographer of the Navy (CN0-N096), the Office of Naval Research, and the Naval Postgraduate School formalized the establishment and support for a Battlespace Environments (BSE) Chair at the Naval Postgraduate School (NPS). The BSE Chair will reside in the Graduate School of Engineering and Applied Sciences.

The importance of Meteorology and Oceanography (METOC), Geospatial Information and Services (GI&S), and Precise Positioning, Navigation, and Time (PNT) to the concepts of Network Centric Warfare (NCW), interoperability and transformation has resulted in initiatives by the Oceanographer/Navigator of the Navy (N096) and the Superintendent, NPS, to enhance the education and research content in the sciences of METOC, GI&S, and PNT. Battlespace Environments (BSE) issues affect all warfare areas and can directly impact the Naval and Joint Warfare Commander's ability to effectively and efficiently complete their missions. The synergy of the NPS Research and Education Institutes, Research Centers, and Space Systems Academic Group make it an ideal location for a BSE Chair. The chair is expected to provide direction for the METOC curriculum, coordination for collaborative activities across NPS Departments, Centers, and Institutes, and guidance for applied student theses.

The incumbent will serve as a senior advisor for NPS's Meteorology and Oceanography (METOC) curriculum. The incumbent will provide a continuous link to N096/ONR/Commander Naval Meteorology and Oceanography Command (CNMOC) to ensure the Naval Oceanography Program is adequately represented in: 1) the development and implementation of the METOC curriculum; 2) coordination of research with NPS Research and Education Institutes and other organizations; and 3) the focus of thesis research by METOC students. Recommendation for the Chair will be made by N096, ONR, and NPS.

## **MEMORANDUM OF UNDERSTANDING WITH AIR UNIVERSITY PROVIDES AIR FORCE FELLOWS AT THE NAVAL POSTGRADUATE SCHOOL**

The Air Force Fellows Program selects senior service school eligible officers each year to study at major university and think tanks. This program is administered under the auspices of Headquarters, Air University, and sponsored by the Deputy Chief of Staff, Plans and Operations, Headquarters, United States Air Force. A Memorandum of Understanding between the Naval Postgraduate School and United States Air Force's Air University establishes an Air Force Fellow within the Special Operations Curriculum at the Naval Postgraduate School.

The Air Force Fellowship is designed for the professional education of a senior service school Air Force officer in the areas of: security problems facing the U.S. and its allies, East Asian security, the future of war, inter-civilizational politics in the post-Cold War world, and the U.S. Military in Post-Cold War American Society.

The Air Force Fellows Program has five objectives: 1) give Air Force officers with demonstrated potential for future leadership insight into civilian defense policy community thinking, broader overall perspectives, and sharper executive skills; 2) provide an additional avenue for the Air Force and DoD to maintain and improve their awareness and understanding of current thought by respected security scholars on defense policy and strategy issues; 3) place experienced officers in civilian institutions of policy research to communicate to these institutions an Air Force perspective on national security issues, military doctrine, military strategy, and USAF views on air and space power; 4) provide selected officers with an opportunity to research, write, and speak on issues of immediate or ongoing concern to the Air Force and the nation; and 5) facilitate academic and intellectual exchange between Air Force and civilian defense scholars.

Each Air Force Fellow has the opportunity to present Air Force and DoD views before nationally recognized scholars, foreign dignitaries, and leading political analysts. Conversely, the Air Force Fellow gains valuable perspectives from these leading thinkers.

# SHORT COURSES

## DESIGN, PERFORMANCE AND ANALYSIS OF UNMANNED AERIAL VEHICLE SYSTEMS SHORT-COURSE

The Naval Postgraduate School will present the Design, Performance and Analysis of Unmanned Aerial Vehicle Systems Short-Course 7-11 April 2003. This course is intended for military officers and civilians who have a technical interest in the design of Unmanned Aerial Vehicles (UAVs) and Unmanned Combat Air Vehicles (UCAVs). This program is of special significance since it concentrates on the current missions and operations as well as Measurements and Signals Intelligence (MASINT), sustainability and force effectiveness. Also included are sessions on training of UAV operators and the human factor issues of crew station design. Special emphasis is given to safety and reliability concerns. Vehicle design tradeoffs, design of the payloads and links, navigation, guidance and control for weapons delivery, and the design of UAV antenna systems are also presented. A special plenary session will cover the evolution of the NATO Standardization Agreement (STANAG) 4586, the standard interface of unmanned control systems for NATO UAV interoperability and the key to successful coalition operations in the future.

This Short Course will provide an excellent opportunity for exchanging information on UAV and UCAV technology. A summary of the program is provided below. Registration information is available at [http://ocf.nps.navy.mil/npsconferences/uav\\_short\\_course/](http://ocf.nps.navy.mil/npsconferences/uav_short_course/).

### Introduction to Missions, Operations and Advanced Concept Technologies

- New service requirements for UAV/UCAVs are and why they keep changing.
- Non-lethal and lethal mission problems and how UAVs complement manned aviation.
- How UAVs are being used in Afghanistan and Iraq (OEF, OSW).
- Usefulness in search and rescue missions.
- Advanced concept technologies being explored.

### Introduction to Measurement and Signatures Intelligence (MASINT)

- Introduction to MASINT as an intelligence discipline and its relationship to Signals Intelligence and Imagery Intelligence.
- Roles and responsibilities of the Central MASINT Organization.
- Six different technical areas that comprise MASINT and

how this information is used by national policy makers and warfighters.

- What MASINT collection implies to UAV sensor and data distribution design.

### UAV Sustainability, Force Effectiveness

- Number of UAVs, of given types and payload configurations needed to provide specified regional coverage and find and identify potential mobile targets such as SAMs, TELs, tanks, etc., with specified probability, and with acceptably small misidentification and false alarm probability. Investigate effectiveness of swarming (small) UAVs.
- UAV regional coverage and target-finding as function of (1) platform, sensor, and communications air frame, propulsion, landing and recovery, and payload reliability, (2) maintenance and diagnostic assets and personnel furnished, (3) human factors and training issues.

### UAV System Safety and Reliability

- Issues of safety, reliability and maintainability of UAV systems.

### The "Man" in Unmanned Systems

- Overview of human factors issues including crew station design, the man-machine interface, and human oversight of autonomous systems.
- Service specific issues of UAV operator selection, training and performance.
- Required crew complement for 24/7 operations for various UAV systems.
- Crew work/rest schedule for a given UAV system.
- Projected human operator performance characteristics with various manning schedules and assessing the performance decrement resulting from reduced manning.

### Vehicle Design

- Design goals and desired mission of a vehicle configuration.
- Power and thrust estimation, endurance and range, slowest speed and top speed.
- Payload weight estimation.
- Needs determination to carry out a mission (how

--continued on page 27

# SHORT COURSES

## TECHNOLOGY REVIEW AND UPDATE: A SHORT COURSE FOR TECHNICAL PERSONNEL AND DECISIONMAKERS

The success and popularity of this short course is ensured by recruiting outstanding experts from industry, academia and the government and by constantly fine tuning the contents.

The course is intended for military and civilian technical personnel and decision-makers that need to refresh and update their technical knowledge. The course provides an excellent overview of key technologies, stressing practical aspects and providing insight into trends.

A summary of this year's program is provided below. Registration information can be found on line at [www.sp.nps.navy.mil/trau](http://www.sp.nps.navy.mil/trau).

### Internet Security – Opportunity or Oxymoron

- The Problem – Threats and Vulnerabilities
- Internet Components of Consequence
- Electronic Commerce – Where Security Matters
- Cyberspace Map and Compass – Finding Solutions

### Electro-Optical and Infrared Systems

- Laser Designators, Precision-Guided Munitions
- Missile Warning Receivers
- Night Vision and Thermal Imaging
- High Energy Laser Weapon Systems

### Optical Sensing Technology

- Overview
- Fiber-optic Technology Relevant to Sensors
- State of the Art of Optical Sensors
- Case Studies of Optical Sensors

### Micro-Electro-Mechanical Systems (MEMS)

- Introduction to MEMS
- Physical Principles for Sensing and Actuation
- Processing Silicon for Use in MEMS
- MEMS Examples: Past, Present and Future

--continued on page 28

## UAV SYSTEMS SHORT COURSE, *continued from page 26*

many UAVs, how often, how long) or assessment of the opponent's mission.

- Estimation of extended capabilities for the Global Hawk and the turboprop Predator B.

### Payloads and Links

- Various trade-offs in receivers for COMINT, emitter location and datalinks.
- Basic jamming relationships to UAV applications.
- Architectures for today's chemical and biological detectors.
- Multiple payload restrictions.
- Radar payloads as well as imagery payloads including link impact, video compression techniques used.
- Link performance and performance of spread spectrum modulations.
- Link-16 structure, SatCom link structure and the application of laser communications.
- Capabilities and information/operation (I/O) of Angel Halo, Hawk Link and other similar links.

### UAV Design and Payload Tradeoffs

- Design and use of UAVs dependence on operational objectives, and how tradeoffs can be accomplished using measures-of-effectiveness.

### Antenna Systems for UAVs

- Trade-offs in designing antenna systems for UAV DF, radar.
- Wireless power required for flight (LOS).
- Effect of indoor and urban propagation issues.
- Design of low cross section UAV vehicles in IR, RF, and Visual.

### Case Study in UAV Development: Global Hawk

- Evolution of the Global Hawk from Advanced Concept Technology Development (ACTD) through current acquisition status.
- Requirements and tradespace constraints and understand why certain trades were made during its development.
- Transition from ACTD to standard acquisition program and understand the pitfalls and issues in this process.

### Navigation, Guidance and Control of UAVs for Weapons

- Navigation in earth-centered inertial coordinates.
- Basic guidance and control laws.
- Guidance and control using UAV aerodynamic surfaces.
- UAV target hand-off requirements for successful engagements (ground, air, ballistic missile targets).

For additional information, contact **Professor Phillip E. Pace**, Course Director, at 831-656-3286 or by e-mail [pepace@nps.navy.mil](mailto:pepace@nps.navy.mil).



## SHORT COURSES

### NATO'S RESEARCH AND TECHNOLOGY ORGANIZATION (RTO) SPONSORS MICRO-ELECTRO-MECHANICAL-SYSTEMS (MEMS) LECTURE SERIES AT NPS

NATO's Research and Technology Organization (RTO) is the single focus in NATO for defense research and technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defense research and technology and to meet the military needs of the alliance, to maintain a technological lead, and to provide advice to NATO and national decision-makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective coordination with other NATO bodies involved in R&T activities.

RTO builds upon earlier cooperation in defense research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defense Research Group (DRG). AGARD and the DRG

share common roots and provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

The RTO will sponsor a MEMS (Micro-Electro-Mechanical-Systems) Aerospace Applications Seminar at the Naval Postgraduate School on 3 and 4 March 2003. MEMS are miniature devices, which integrate actuators, sensors, and a processor (controller) to form intelligent systems. They are characterized by their close relationship to integrated-circuit components both in terms of manufacturing techniques and their potential for integrations with electronics. After its emergence in the late eighties, MEMS has developed into billion dollar commercial markets, in particular in the automotive, medical, and telecommunication fields. The Lecture Series will address applications in the aerospace field, which encounter unique challenges related to harsh environment conditions and reliability requirements.

After an introduction into MEMS technology, six aerospace applications will be described where MEMS will enable the development of potentially new capabilities. They will allow introduction of low-cost, high-end functionality and thereby will enhance performance and extend lifetimes. For these applications, the status, R&D needs, barriers of implementation, and insertion strategies will be discussed.

Aerospace applications include (1) active control of thin boundary layer flows with the potential to eliminate conventional flight control surfaces, reduce drag, provide lift-on-demand, and enhance aerodynamic performance of compressors, turbines and low-observable intakes, (2) complete inertial and navigation units on a single chip which offer major advantages in terms of size, weight and cost over conventional systems, (3) fusing/safety and arming systems for torpedo applications, (4) micro power generation using micro fuel cells and micro engines for potential standalone sensors and actuators with wireless communication, and micro rockets, (5) applications in harsh environments (e.g., high temperatures, large number of vibration cycles, erosive flows, and corrosive media), and (6) applications for autonomous inventory and storage environments monitoring and for service life predictions. The final lecture will introduce MOEMS (Micro-Optic-Electro-Mechanical-Systems) in the context of optical communication & sensing systems.

For further information about the MEMS Lecture Series, call **Professor Rudy Panholzer** at 831-656-2154 or e-mail [rpanholzer@nps.navy.mil](mailto:rpanholzer@nps.navy.mil).

#### TECHNOLOGY REVIEW AND UPDATE,

*continued from page 27*

##### Integrated Circuits

- Introduction to Analog and Digital Integrated Circuits
- High Speed Electronic Systems Design
- Programmable Logic
- The Future of Integrated Circuits

##### Bioengineering and Biotechnology

- Biomedical Sensors and BioMEMS
- Biotechnology, Genomics, and Proteomics
- Biomaterials and Tissue Engineering
- Bioinformatics and Biological Warfare Agents

##### Military Satellite Communications Technology

- Introduction to Military Satellites Communications and Network-Centric Warfare
- Present and Future Narrow-band and Wide-band Satellite Communications
- Present and Future Protected Satellite Communications
- Military Use of Commercial Satellite Communications Systems

##### Satellite Communication Technologies and Trends

- The Satellite Communications Revolution
- GEOs, MEOs and LEOs on the Horizon
- Key Drivers and Enabling Technologies
- Next Generation Satellite Communications Systems

### NORTHROP GRUMMAN AWARD FOR EXCELLENCE IN SYSTEMS ENGINEERING AND INTEGRATION

In recognition of its commitment to national security and the importance of assisting in the technical education of the United States and foreign military officers, Northrop Grumman has provided support to the NPS Foundation Inc. This support focuses recognition on faculty and students for excellence in Systems Engineering and Integration (SEI) and culminates in an award presentation at December graduation.

Senior Lecturer David Olwell was selected by the graduating class of SEI students for recognition of excellence and innovation in program development, teaching, and research in support of the Systems Engineering and Integration curriculum. Also recognized were Research Professor John Osmundson, Department of Information Science, and Professor Chuck Calvano, Department of Mechanical Engineering, for innovation research and faculty leadership on national defense systems and capabilities in the SEI Expeditionary Warfare Integration Project. SEI graduating students recognized for demonstrated leadership and innovation include LCDR Aaron Scott Peters,



Senior Lecturer David Olwell celebrates with December graduates of the Systems Engineering and Integration Curriculum.

USN, MAJ Chee Yang Kum, Singapore Navy, MAJ Poh Seng Wee Patrick, Singapore Navy, LTC Loh Kean Wah, Singapore Air Force, and CDR William Kurt Erhardt, USN.

### NPS GRADUATE AND ASTRONAUT JOINS NPS FACULTY

Captain Dan Bursch, USN, joined the Naval Postgraduate faculty as a member of the Space Systems Academic Group in January 2003. He has been an astronaut since 1990, when he was selected for the program while a student at NPS. CAPT Bursch received his B.S. from the U.S. Naval Academy and a M.S. in Engineering Science from NPS in 1991. He is also a graduate of the Naval Test Pilot School.



CAPT Dan Bursch, U.S. Navy

CAPT Bursch's Navy experience includes Bombardier/Navigator on an A-6 Intruder, VA-34, an U.S. Naval Test Pilot School Instructor, and Strike Operations Officer, Cruiser-Destroyer Group One. His technical assignments as an astronaut included work on the shuttle cockpit display upgrade, the capsule communicator (CAPCOM), and the space station caution and warning system. His astronaut flight experience includes a total of four missions totaling 227 days in space. His most recent flight was on the International Space Station (ISS) from December 2001 to June 2002 for 196 days. He shares the U.S. endurance record with his crewmate, Col Carl Walz, USAF. Specific missions include STS-51 *Discovery* (1993), STS-68 *Endeavour* (1994), STS-77 *Endeavour* (1996), STS-108 *Endeavour* (2001), and STS-111 *Endeavour* (2002).

CAPT Bursch hopes that the assignment of a Naval Astronaut to NPS will bring a unique perspective to the Space Systems Academic Group including:

- Giving the students an operational perspective of living and working in space;

--continued on page 30

## FACULTY NEWS

### **GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY**

K. Gue, R. Meller, and J. Skufca, "Deciding Between Zone and Batch Picking in an Order Fulfillment Center," INFORMS Conference, San Jose, CA, November 2002.

L.R. Jones, "Careers in Budgeting and Financial Management," Annual Conference of the Association for Budgeting and Financial Management, Kansas City, MO, October 2002.

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A. Talalayevsky and I. Lewis, "Automobile E-Tailing: New Channels or Intermediaries," 2002 Decision Science Institute Conference, San Diego, CA, November 2002.

### **GRADUATE SCHOOL OF ENGINEERING AND APPLIED SCIENCES**

#### **AERONAUTICS AND ASTRONAUTICS**

C.M. Brophy, S. Werner, and J.O. Sinibaldi, "Performance Characterization of a Valveless Pulse Det-

--continued on page 31

### **ASTRONAUT JOINS NPS FACULTY, continued from page 29**

- Better relating deployments in space with Naval deployments;
- Forming stronger ties between the Navy and NASA;
- Coordinating new thesis topics at the Johnson Space Center, as well as the other NASA Centers;
- Stimulating interest in Space Systems research;
- Enhancing educational opportunities for Space Systems students in the area of civilian and commercial space;
- Acting as liaison between NASA and NPS on matters pertaining to teaching and research in the area of Space Systems.

CAPT Bursch also hopes to gain knowledge and experience in the field of unmanned space flight.



## FACULTY NEWS

--continued from page 30

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### APPLIED MATHEMATICS

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F. Taboada, A. Lima, J. Gau, and **P.E. Pace**, "Intercept Receiver Signal Processing Techniques to Detect Low Probability of Intercept Radar Signals," *Proceedings of the IEEE, 5<sup>th</sup> Nordic Signal Processing Symposium*, Hurtigruta Tromso-Trondheim, Norway, November 2002.

### MECHANICAL ENGINEERING

**Prof. T. Sarpkaya** has been included in the exclusive commemorative testimonial of the One Thousand Great Scientists of the International Biographical

Centre of the University of Cambridge for his outstanding scientific achievements in hydrodynamics.

### OCEANOGRAPHY

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**P.C. Chu** and **C.W. Fan**, "Finite Volume Ocean," Oceans 2002, IEEE and Marine Technology Society, Biloxi, MS, October 2002.

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--continued on page 32



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--continued from page 31

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S. Elgar, B. Raubenheimer, and T.H.C. Herbers, "Bragg Reflection of Ocean Waves from Sandbars," *Geophysics Research Letter*, 2003 (in press).

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L.N. Ly, R.P. Stumpf, T.F. Gross, and F. Aikman, III, "Modeling of Cross-Shelf Transport in Support of Monitoring and Forecasting of Harmful Algal Blooms Along the West Florida Coast," Tenth International Conference on Harmful Algae, St. Pete Beach, FL, October 2002.

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## PHYSICS

J.A. Rice and J.T. Hansen, "Wideband Link-Budget Analysis for Undersea Acoustic Signaling," First Pan-American/Iberian Meeting on Acoustics, Cancun, Mexico, December 2002.

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band Link-Budget Analysis for Undersea Acoustic Signaling," 144<sup>th</sup> Meeting of the Acoustics Society of America, Cancun, Mexico, December 2002.

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## GRADUATE SCHOOL OF OPERATIONAL AND INFORMATION SCIENCES

### INFORMATION SCIENCE

D. Brutzman, *Real Time Graphics* Interview, Vol. 11, No. 6, January 2003.

### OPERATIONS RESEARCH

K. Cormican, "Protecting Packet-Switched Communications Networks," INFORMS Annual Meeting, San Jose, CA, November 2002.

Prof. D. Olwell was appointed as the Publications Officer for the New American Statistical Association section on National Defense and Homeland Security, 2002.

Prof. D. Schrady was awarded 'Fellow' status by the Institute for Operations Research and the Management Sciences at the INFORMS National Meeting in San Jose, CA, November 2002.

L.D. Smith and S. Sanchez, "Estimating Business Potential for Supermarkets: A Statistical Approach for Site Selection and Performance Review," *Proceedings, 2002 Decision Science Institute Conference*, November 2002.

K. Wood and S. Sanchez, "The BEST Algorithm to Solve Stochastic Interger Programs," INFORMS Annual Meeting, San Jose, CA, November 2002.

## SCHOOL OF INTERNATIONAL GRADUATE STUDIES

### DEFENSE RESOURCES MANAGEMENT INSTITUTE

F. Handy and N.J. Webb, "A Theoretical Model of the Effects of Public Funding on Savings Decisions by Nonprofit Service Providers," *Annals of Public and Cooperative Economics*, 2002 (in press).

F. Handy and N.J. Webb, "To Save or Not to Save: Aspects of Savings Decisions by Charitable Organizations," in *Delicate Dancers: Partnerships Between Nonprofit Public and Private Sector*, K. Brock and K. Banting, eds., McGill-Queen's University Press, Kingston, Canada, 2002 (in press).

J. Martinez-Vazquez and R. McNab, "Fiscal Decentralization and Economic Growth," *World Development*, 2002 (in press).

R. McNab and S. Everhart, "Rethinking International Aid: Governance, Growth, and the Millennium Challenge," *Business and Economic Review*, 2002 (in press).

Prof. N.J. Webb presented research on new theory of philanthropy at the Annual Association on Nonprofit Research and Voluntary Action Meeting in Montréal, Canada, November 2002

## THE MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION INSTITUTE

M. Zyda, "Entertainment R&D for Defense," *IEEE Computer Graphics and Applications*, January/February 2003.

M. Zyda, "Weapons of Mass Distraction: America's Army Recruits for the Real War," Naval War College, Providence, RI, December 2002.

Prof. M. Zyda has been appointed to the National Research Council's Committee for the review of NASA's Revolutionized Aviation Program.

## FEATURED PROJECT

### DIGITAL TARGET IMAGING ARCHITECTURE, *continued from page 3*

and complex project and has involved a team of many students and the co-principal investigators performing circuit design, circuit simulation, and IC fabrication mask design and verification. The Office of Naval Research has provided additional funding to pay for fabrication. After fabrication, the chip will be tested at the NPS before delivery to the Tactical Electronic Warfare Division at the NRL, Code 5740.

The follow-on effort for this project has already started. The follow-on effort involves the design and development of a mixed-signal electronic warfare system on a chip, which would include the DIS-512, the DRFM, and the required A-to-D and D-to-A converters. It has been briefed to ONR and received excellent response. Full funding is anticipated for this project for FY04. When completed, this chip will allow an entire digital imaging electronic attack system to fit on a small host platform, such as a UAV.

#### Transition to Fleet

The Tactical Electronic Warfare Division at the NRL, Code 5740, is currently designing and constructing the new type of digital radio frequency memory (DRFM) that is required

in order to use the DIS-512 in an electronic attack system. When fabrication of the DIS-512 is complete and testing has finished at the NPS, it will be sent to the NRL for integration into the new DFRM. This is currently scheduled for FY03/Q4. The new DFRM with the DIS-512 is scheduled for integration into the Advanced Multifunction Radio Frequency Concepts (AMRFC) test bed for sea trials. Sea trials are expected to begin FY04/Q1.

#### Impact on Navy/DoD

This research project and the DIS-512 are critical to fleet protection. This project has been briefed twice per year for the last two years to Code 5740 at the NRL, the Tactical Electronic Warfare Division, and to ONR Code 313, Platform Protection. It has also been briefed every year at the ONR-sponsored Electronic Warfare gathering. It has always been rated as one of the highest priority research projects at this gathering. It has also been briefed to Rear Admiral Burns, Commander, Naval Security Group Command, and to Rear Admiral Brewer, Commander, Naval Sealift Command.

*--continued on page 35*

### A DIGITAL ASIC FOR SYNTHESIZING FALSE TARGET RADAR IMAGES, *continued from page 3*

to baseband as described by

$$s(t) = \text{rect}\left(\frac{t}{T}\right) e^{j2\pi(f_d \text{PRI} + \frac{Kt^2}{2})}$$

where  $f_d$  is the Doppler frequency between the radar and the DIS platform intercepting the chirp signal and PRI is the pulse repetition interval.

After sampling and digitization, the phase samples are used by the DIS to synthesize a complex false target image. This image is converted back to an analog signal, applied to the up converter, and amplified for transmission back to the interrogating radar. The entire system operates under control of the microprocessor, which also programs the DIS with the parameters necessary to synthesize the false target image(s) desired by the system operator.

*--continued on page 34*

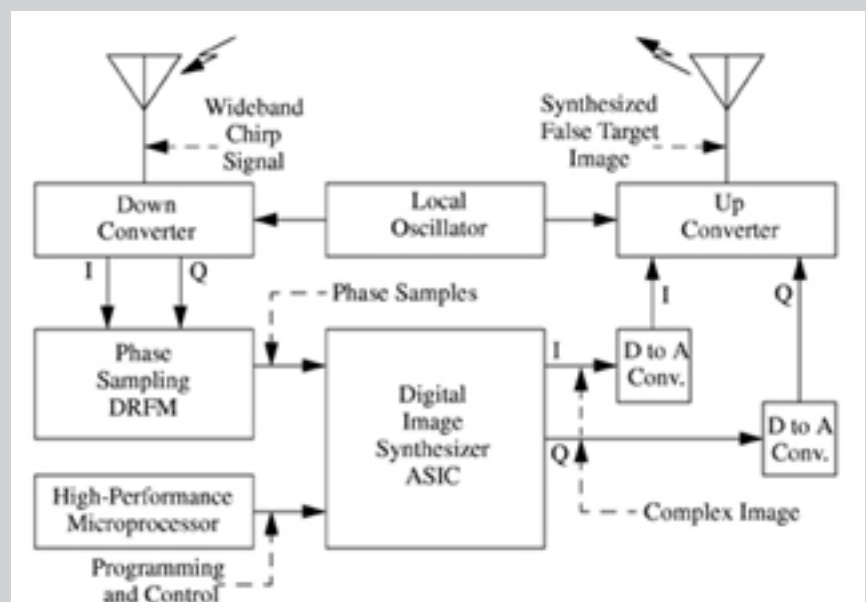


Figure 2. Block diagram of the false target radar image synthesizer system.

# FEATURED PROJECT

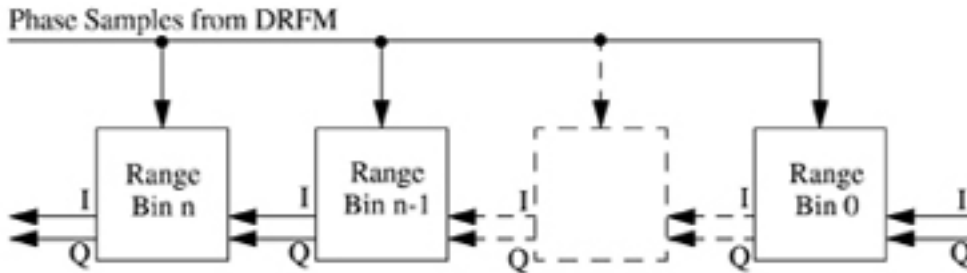
## A DIGITAL ASIC FOR SYNTHESIZING FALSE TARGET RADAR IMAGES, *continued from page 33*

The architecture of the DIS is shown in Figure 3 and the architecture of each range bin is shown in Figure 4. Referring to Figure 4, operation of the DIS starts when the control microprocessor independently programs the phase rotation and gain for each range bin. To improve performance, these

the summation adder in the following range bin. The summation adder outputs for the range bin on the far left side of the cascade are the primary outputs of the DIS that go to the DAC.

To provide a proof-of-concept DIS at a reasonable cost, the initial implementation of the DIS used the design shown in Figures 3 and 4 but with only 8 range bins. To reduce costs even further, the chip was fabricated through MOSIS using the HP/Agilent 0.5 mm N-well process. The IC has a total of 81,632 transistors, 79,896 in the core and 1,736 in the pad circuits. A photograph of the

*--continued on page 35*

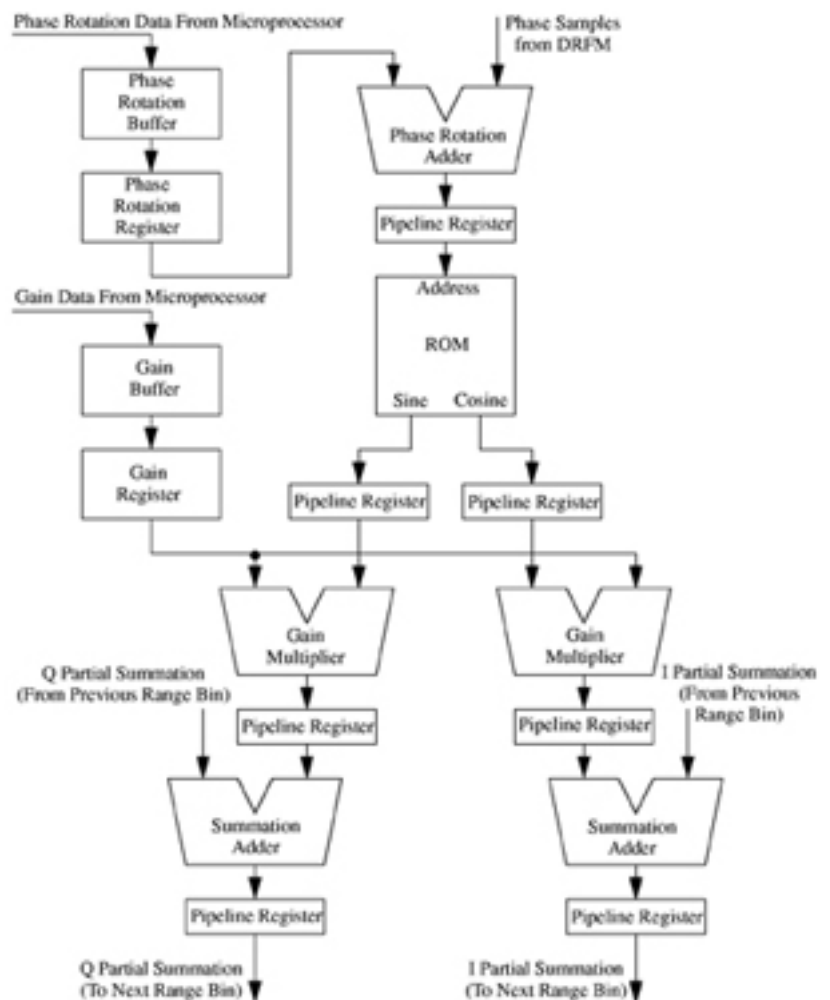


**Figure 3. Architecture of DIS.**

inputs are double buffered to allow the microprocessor to reprogram the DIS while the IC is still finishing calculations using previous programming. After the gain and phase coefficients are loaded, a sequence of phase samples from the DRFM is clocked into each range bin. Each range bin loads the same phase sample on the same clock, as shown in Figure 3, and processes the same phase sample on the same clock.

To improve the performance of the DIS, the range bin architecture shown in Figure 4 is heavily pipelined. The phase samples from the DRFM are added to the value in the phase rotation register and the result is stored in a pipeline register. The output of the pipeline register is then applied to the combined sine/cosine ROM lookup table. The ROM outputs are applied to the gain multipliers via additional pipeline registers. The output of each gain multiplier goes to another pipeline register.

After multiplication, the data from each range bin is added to the data from all the other range bins. This is accomplished using a cascade of 2-input, pipelined adders. Referring to Figure 3, the I/Q partial summation inputs to the adders come from the outputs of the summation adders in the previous range bin. For the range bin at the far right side of the cascade, the adder inputs are 0. The outputs of the summation adder in each range bin are connected to the partial summation inputs of



**Figure 4. Architecture of range bin implementation.**

## FEATURED PROJECT

### DIGITAL TARGET IMAGING ARCHITECTURE, *continued from page 33*

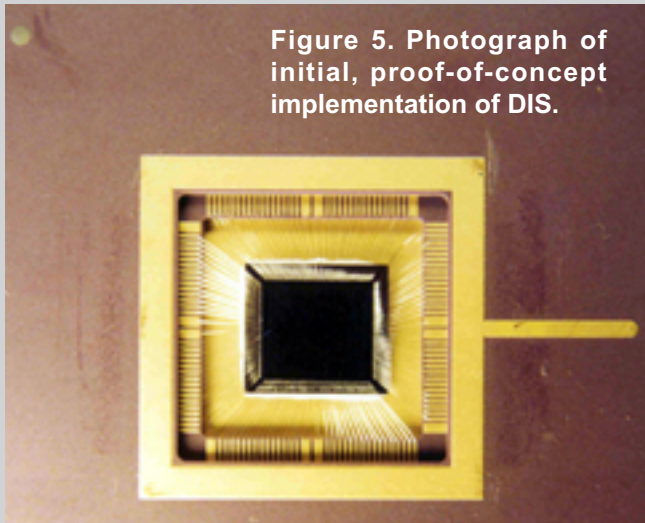
Admiral Brewer considers the project extremely important to the Sealift Command because their ships are noncombatants. This technology will provide a tremendous increase in self-defense capability to unarmed transports, tankers, and freighters that are still required to travel into hostile waters. It

should be noted that for combatants, the chip being developed will do a lot more than just restore the ability the U.S. and allies are loosing as potential adversary nations deploy wideband imaging ISARs. This new, fully programmable,

*--continued on page 36*

### A DIGITAL ASIC FOR SYNTHESIZING FALSE TARGET RADAR IMAGES, *continued from page 34*

packaged die is shown in Figure 5. The size of the core is approximately 5.1 by 5.6 mm. The size of the outside of the pad frame is approximately 5.5 by 6.1 mm. The IC was packaged in a 132-pin PGA and has 126 I/O, 2 power, and 2 ground pins.



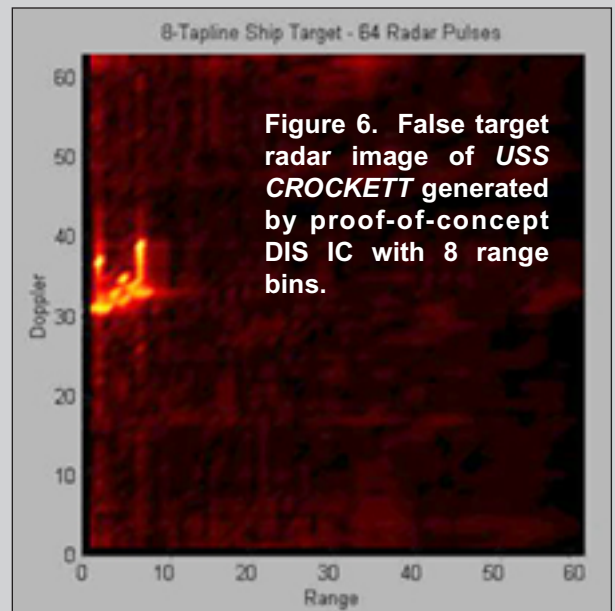
**Figure 5. Photograph of initial, proof-of-concept implementation of DIS.**

Initial testing was conducted at a clock speed of 10 MHz. All 25 of the packaged ICs were confirmed to be 100% functional. At this point, 16 of the ICs were shipped to the U.S. Naval Research Laboratory in Washington, D.C. for incorporation into an electronic countermeasures test bed. Testing continued on the remaining ICs and all chips worked correctly up to a maximum speed of 71 MHz, slightly greater than the 66 MHz maximum speed predicted by simulations. Average power consumption was measured at 0.132 W at 70 MHz with a 3.3 V supply.

With only 8 range bins, multiple proof-of-concept DIS chips would need to be cascaded together to achieve the resolution shown in Figure 1b. Figure 6 shows the image a single DIS chip is capable of generating. Despite only 8 range bins, the hull,

bridge and quarterdeck, and forward and aft masts are all distinguishable.

Once the prototype IC had proven the feasibility of the architecture, the sponsor then provided additional funding to design a full-scale, custom IC to implement the full digital image synthesizer architecture with 512 range-bin processors on a single chip (DIS-512). The DIS-512 design incorporates several new and innovative circuits, including a high-speed, pipelined, multistage, summation adder, a high-speed sine/cosine lookup table ROM, and a novel input data conversion circuit that utilizes the CORDIC algorithm. The chip also uses a new method for distributing clock and control signals to the 512 different processors that includes a novel clock phasing adjustment circuit. At this point in time, the design of the entire circuit is complete and the design of the full-custom ASIC is approximately 90% complete. The 700 MHz, 6 million transistor chip is scheduled for fabrication in FY02/Q2 at Taiwan Semiconductor Corporation using a state-of-the-art, 0.18 micron, CMOS process with 6 layers of Cu interconnect.



**Figure 6. False target radar image of USS CROCKETT generated by proof-of-concept DIS IC with 8 range bins.**



## FEATURED PROJECT

### HOW OPTIMIZATION GUIDES ARMY BASE CLOSURE AND REALIGNMENT, *continued from page 5*

mented as a cost per soldier or civilian assigned to an installation. OSAF uses a variable cost based on these cost categories:

- base operating support,
- sustainment repair and modernization,
- medical,
- locality pay, and
- housing operations and allowances.

*Implementation Costs:* All stationing actions that include the movement of a unit or closure of an installation incur one-time costs in military construction (MILCON), transportation, and program management. If an installation that receives a new unit does not have the required green-rated facilities or ranges available, then a one-time MILCON cost is assessed for new construction or (if available) an upgrade from other-rated facilities.

All unit movements incur a one-time transportation cost that includes the movement of civilians, equipment, military families, and the military unit.

#### Evaluating a Stationing Plan

OSAF prescribes stationing plans that we evaluate using the following six metrics:

- *NPV and Investment* is the 20-year NPV of the stationing plan as well as the one-time cost for transportation, MILCON, and program management.
- *Complexity* is measured by the number of units moved.

• *Joint Possibilities* reveal impact on inter-service stationing as suggested by the Government Accounting Office (GAO) and others stressing the importance of installation use by more than one service in future stationing analyses. (We are investigating how to expand OSAF for use with the other services.)

- *Utilization Factors* are reported for facilities, ranges, and lands where a low utilization rate could justify the mothballing or demolition of facilities.
- *Impact Assessment* is more subjective and includes a panel's review for unique requirements not captured in OSAF such as: strategic implications, quality of life, mobilization, environmental issues, and deployment. Strategic implications represent the Army's ability to fulfill its mission mainly from a geographical perspective. For example, the Army cannot station all forces on one coastline or a preponderance of forces in Alaska. We examine quality of life using standard Army metrics for an installation and its surrounding community. Environmental assessment includes remediation costs and an examination using a standard Army model. For unit deployment and mobilization requirements, we determine if the stationing of a large maneuver force will stress existing deployment infrastructure (e.g., railheads and airfields) at the unit's

*--continued on page 37*

### DIGITAL TARGET IMAGING ARCHITECTURE, *continued from page 35*

digital imaging technology can be used to simultaneously generate multiple false targets of any size, and to give those false targets realistic motion. It could even synthesize an entire naval battle group. Furthermore, because of the single-chip implementation, multiple false target radar image generators deployed on different platforms in a battle space environment could be networked to provide electronic protection for an entire fleet of ships. It should also be noted that the DIS-512 can be programmed to generate images of other objects besides ships.

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D. J. Fouts, P. E. Pace, "False radar target digital image synthesizer," Patent NC 83,887 filed 1 May 2002.

P. E. Pace, R. E. Surratt, S. Yeo, "Signal Synthesizer and Method Therefore," Patent NC 79,429, filed 1 September 1999.

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## FEATURED PROJECT

### HOW OPTIMIZATION GUIDES ARMY BASE CLOSURE AND REALIGNMENT, *continued from page 36*

new location.

- *Other.* Each installation has its own set of “political” considerations. If a political constraint is added to the model, OSAF can determine the cost of imposing the constraint.

#### Results

*Data Analysis:* Gathering and analyzing data for a model such as OSAF often provides many insights. In 1997, GAO concluded that the “DoD continues to maintain large amounts of excess infrastructure, especially in its support functions, such as maintenance depots, research and development laboratories, and test and evaluation centers.” We have found excess infrastructure in the OSAF installation types, but not to the extent that GAO reports in support installations. In addition to improving cost and facility utilization, another primary reason to move units is to mitigate the imbalance of training land throughout the Army. When we examine today’s overall Army, there is enough total training land, but with the current stationing, numerous installations cannot meet their unit requirements. By moving units, we can *possibly* improve the balance between available land and unit requirements throughout the Army, but data indicate the majority of training land is in just a few locations. Thus, a full utilization of this land would require extensive relocation and implementation costs including MILCON. Additionally,

the strategic implications could be significant. For example Alaska has over 50 percent of the Army’s light and over 30 percent of its heavy maneuver land, but because Alaska is also one of the highest-cost areas and has environmental restrictions, it is not the ideal location for the preponderance of U.S. forces.

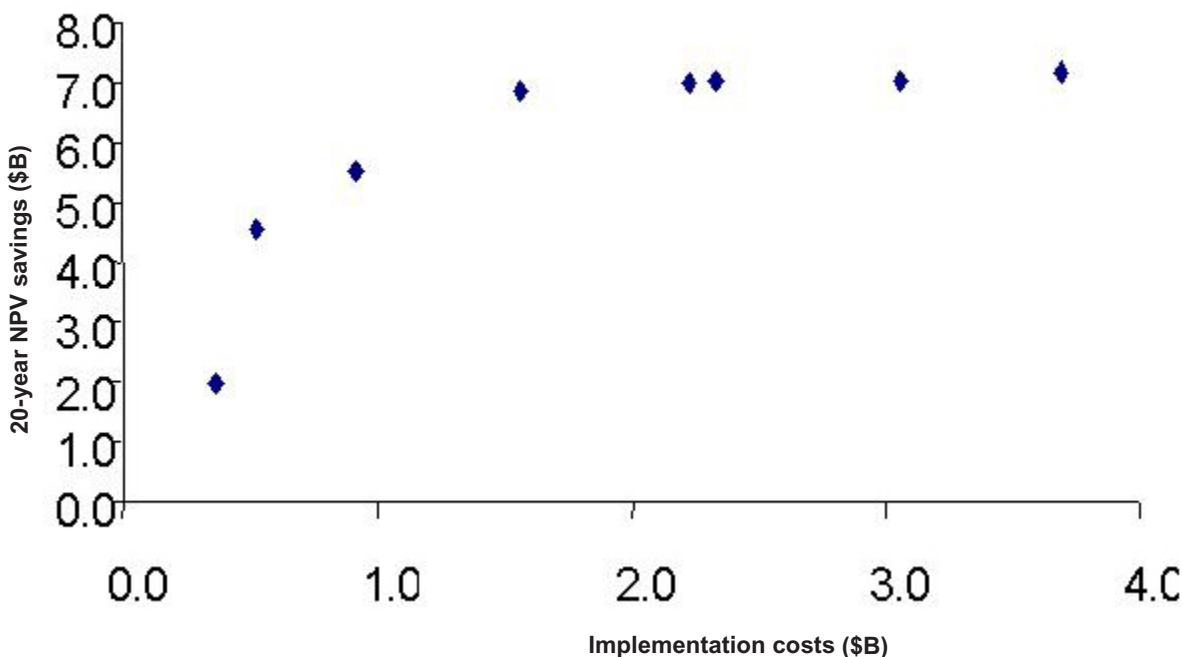
*Potential Budget Savings:* Army unit realignments and base closures have the potential to save the Army billions of dollars (NPV). Savings are not realized for numerous years due to the initial implementation costs involved. Even though stationing actions do not provide short-term savings, they should still be considered and possibly executed for their long-term benefits.

Figure 1 represents eight different notional stationing plans that each minimize NPV subject to a different implementation budget. Each point in the graph is a stationing alternative and represents the 20-year NPV (Y-axis, \$B) at different implementation costs (X-axis, \$B). The XY intersection is the status quo or zero implementation cost. In the notional solution below, an Army investment of about \$1.5B provides most of the 20-year NPV savings.

#### Cost Uncertainty

- *BRAC costs.* The forecast costs in past BRAC actions have been hard to reconcile with subsequent actual costs [GAO 1997].

*-continued on page 38*



**Figure 1.** For these notional stationing plans, an investment of \$1.5 billion allows most of the 20-year NPV savings.

## FEATURED PROJECT

### HOW OPTIMIZATION GUIDES ARMY BASE CLOSURE AND REALIGNMENT, *continued from page 37*

- *Economic assistance.* OSAF does not consider the cost of assistance to local communities to overcome realignment impacts. Although these costs may be substantial [GAO 1996] they are also difficult to estimate in advance of any announced action.

- *Environmental costs.* One of the largest costs DoD can face on an installation is for environmental remediation. GAO [1997] states that “we have concurred with DoD not considering these costs in developing its cost and savings estimates as a basis for base closure recommendations. At the same time, we agree with DoD’s position that environmental restoration costs are a liability to it regardless of its base closure decisions; and we note, these costs are substantial.”

- *Environmental issues other than cost.* Unfortunately, there are many environmental factors that can impact a stationing decision. For example, encroachment (due to growth in the installation’s local community) can complicate new construction. Other installations may have long-term waivers or permits that could influence mission accomplishment. Such issues must be carefully investigated for any BRAC recommendation.

#### Summary and Future Use

OSAF addresses a complex problem – a stationing analysis of the entire U.S. Army. OSAF quickly prescribes an optimal stationing plan for a given set of inputs and stationing restrictions.

We have continuously refined OSAF based on reviews by the Army leadership, our recent analyses to support the 2001 Quadrennial Defense Review, several case study analyses, and our current studies to support recent Army stationing decisions.

Many in DoD have suggested that all services would benefit from a joint analysis using OSAF. We agree that there is much to recommend a joint OSAF effort, but we hasten to warn that developing the data and details necessary to support such a large-scale decision in reasonable detail requires significant, continuing commitment and resources. The Army has made this commitment, and as a result of using optimization also enjoys further benefits:

- All assumptions and constraints for each scenario are documented and stated explicitly. This means that each stakeholder can state a case on a level playing field, with transparency to all others.

- Every optimized plan automatically satisfies all the myriad details expressed in the underlying constraints. This means that comparisons between competing plans can be made quickly without worrying about comparability.
- Every proposed solution is the best that can be achieved under the circumstances. This is a comfort when dealing with contentious decisions involving huge amounts of our national treasure.

#### Additional Reading

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## FEATURED PROJECT

### SINKING A BODY USING BUBBLES, *continued from page 7*

bubbles.

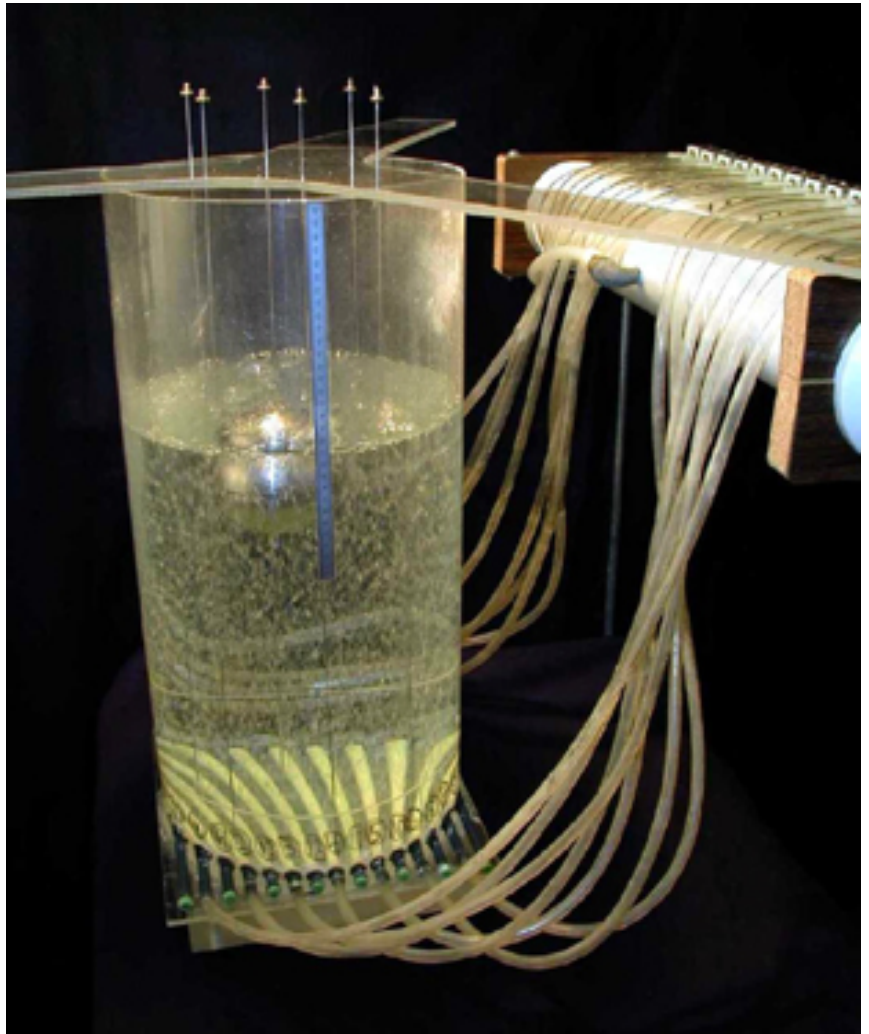
A new apparatus capable of yielding accurate data needed to be built. LT Carl DeGrace, USN, and LCDR Leonard Pringle, Canadian Navy, expressed interest in examining this phenomena for their thesis research. It was decided that they would work together, with LCDR Pringle focusing on the closed environment case, and LT DeGrace finishing this and moving on to the open environment.

Figure 4 shows the tank which was built. The previous work and tests of the bubblers showed that individual control of the air to each bubbler would be necessary for a uniform bubble field, so we built a manifold out of PVC pipe with one gate valve for each of the 15 bubblers.

The flow of bubbles was very sensitive to the settings of the manifold valves. When the bubble flow is not uniform, localized flow regions develop. These have two deleterious effects: the ball drifts to a region of downward flow and sinks at a greater average density than if the flow were uniform, and fluctuations of the surface prevent a precise reading of its height, which is required (see below). New valves with more accurate adjustments solved the problem.

There were many more experimental problems that required time and effort. The most difficult was measuring the average density of the bubbly water. We first tried the simplest method of reading the height of the fluid before and after the bubbles were added. This was not sufficiently accurate, and was also time-consuming because it could not be accurately calibrated against the airflow rate, so we investigated some sophisticated methods to infer the density: speed of sound, capacitance between two conducting plates immersed in the fluid, and videotape-determined bubble velocity combined with airflow rate. However, all of these methods were much less accurate than the simple height measurement method, so we returned to this and were able to refine it so that it was suitable.

LCDR Pringle graduated in June 2000 [7]. Data was taken for ball densities down to three-quarters that of water. We could not go lower because the substantial foam and large



**Figure 4. Apparatus for determining the average density of bubbly water required to sink a hollow stainless steel ball, for different masses of the ball. The tank is 1 foot in diameter. A cage of thin metal rods is used to keep the ball from the wall.**

amount of bubbles prevented our view. The data showed an unexpected and interesting “knee” at a certain average density of the ball. This was very interesting because it could be a transition to a new state of the fluid. We had found a reference about non-Newtonian behavior of bubbly liquids that appeared to support our data. The plan was for LT DeGrace to repeat the entire experiment with the new manifold, and to observe if the behavior was still present. He would also further search the literature.

The back of the new manifold is visible in Figure 4. The

*--continued on page 40*

# FEATURED PROJECT

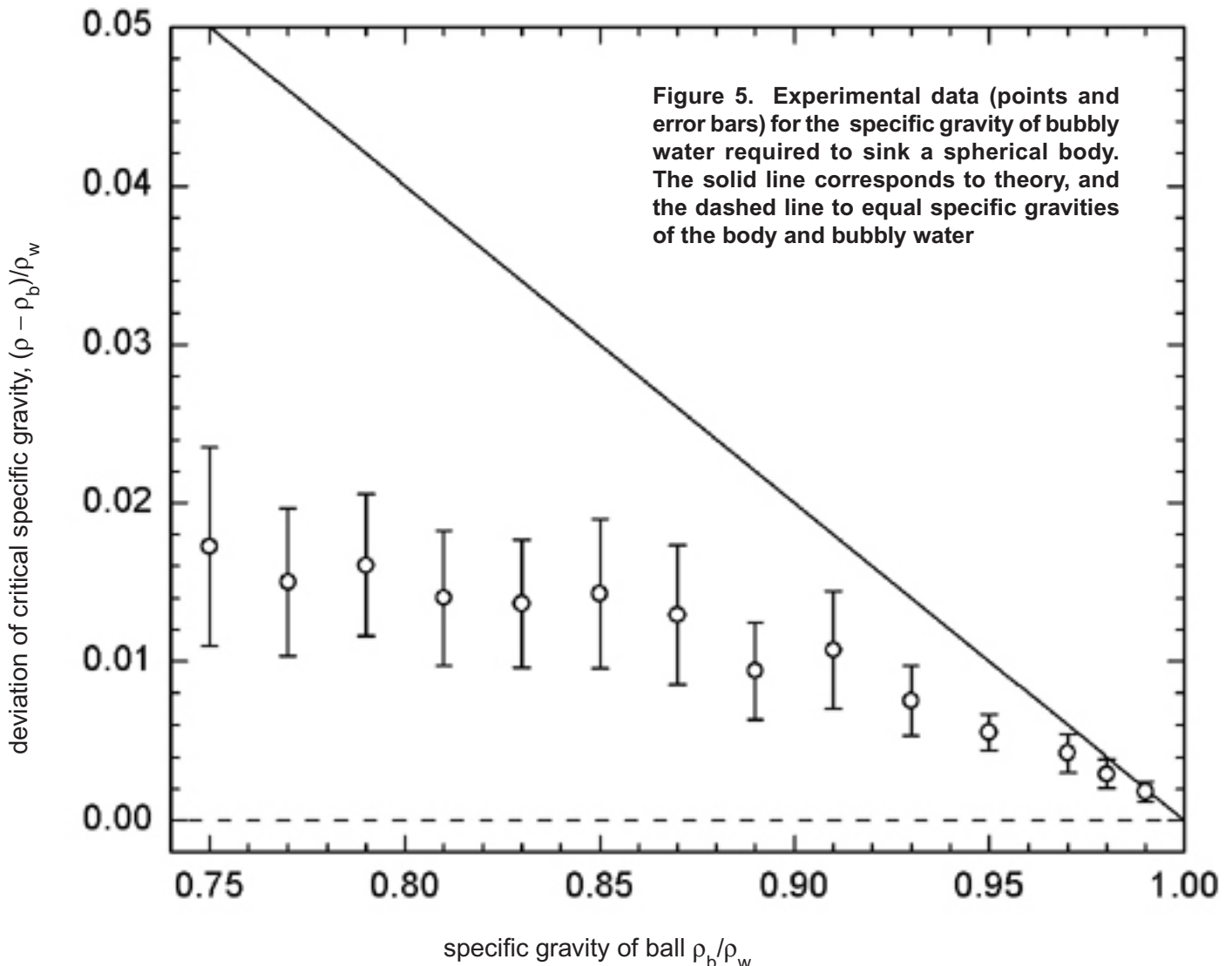
## SINKING A BODY USING BUBBLES, *continued from page 39*

data did not clearly show the presence of the knee, although it could not be ruled out. In addition, the data for low airflow rates (barely buoyant body) was not in complete agreement with the previous data. However, we had to move on to the open environment experiment. We removed the bubbler section of the apparatus in Figure 4 and placed it in the bottom of a much larger tank. We found that bubbles *could* sink the floating ball, even though the upward drag is expected to be significant. However, we could only very crudely quantify the average density of bubbly water. A proper open environment experiment remains to be done.

LT DeGrace graduated in December 2000 [8]. We did not have sufficient faith in the closed environment data,

so we carefully and patiently redid the entire experiment. The results are shown in Figure 5, which we published [1]. The specific gravity of the ball (density divided by the density of water) is along the horizontal axis. Hence, the barely buoyant case is to the right and the highly buoyant case to the left. The vertical axis is the specific gravity of the bubbly water, beyond that of the ball, required to barely sink the ball. The solid line represents our theory, which assumes that directly above the ball there is a shadow region devoid of bubbles. We confirmed this by observing the apparatus for low airflow rates, but were not able to discern whether this was the case for higher airflow rates. The dashed line represents the case if

*--continued on page 41*



## FEATURED PROJECT

### SINKING A BODY USING BUBBLES, *continued from page 40*

there is no shadow region and the bubbles are uniformly distributed (the specific gravity of the bubbly water required to sink the ball is then equal to that of the ball).

For low airflow rates (barely buoyant ball), the data agree with the theory. For greater airflow rates, the data lie between the theory with the shadow region and the case without this region. Note that there is *no* evidence of a “knee” in the data. The simplest interpretation of the data is that the upward drag is negligible and that turbulence causes bubbles to enter the shadow region. This requires a larger bubbly water density (fewer bubbles) to sink the ball, because the fluid above the ball exerts less downward force on the body. We had already tentatively arrived at this conclusion based on the previous data, but did not have the time to pursue the obvious test of performing the experiment with a flat-top body similar to a ship, where there is no region of fluid directly above the body. We presented these results at a conference [6].

An important consequence of our work is that it is motivating other investigators. Two scientists at Monash University in Canada recently submitted a journal manuscript on the sinking of a body by a single large bubble [9], as opposed to our case in which the bubbles are small compared to the body. Graham de Vahl Davis and students at the University of New South Wales in Australia are currently performing numerical and experimen-

tal investigations. I have been advising one of the students, who plans to perform the experiment with a flat-top body. Marine geologist Alan Judd at the University of Sunderland in the United Kingdom is working on a more-accurate modeling of the effects of bubbles on actual ships. Science documentary producer William Aslett of the British Broadcasting Corporation is planning an experiment where bubbles will be generated to sink a boat in the ocean. The author is consulting on this project.

Our research was supported by funds from the Naval Postgraduate School and Naval Sea Systems Command. For the full version of this article, send a request to [denardo@nps.navy.mil](mailto:denardo@nps.navy.mil).

#### References

- [1] Bruce Denardo, Leonard Pringle, Carl DeGrace, and Michael McGuire, “When do bubbles cause a floating body to sink?” *American Journal of Physics* **69**, 1064-1072 (2001).
- [2] “Sunk Without Trace,” *New Scientist* **171**, 12 (29 September 2001). “Bubbling Seas Can Sink Ships,” *NewScientist.com*, 26 September 2001.
- [3] Richard D. McIver, “Role of Naturally Occurring Gas Hydrates in Sediment Transport,” *Bulletin of the American Association of Petroleum Geologists* **66**, 789-792 (1982).
- [4] <http://www.fugro.com>, “Fugro-UDI goes wreck hunting at the Witches Hole,” 6 December 2000.

[5] Private communication from Michael Stumborg, Naval Surface Warfare Center, Dahlgren, Virginia, March 2000.

[6] Bruce Denardo, “When Do Bubbles Cause a Floating Body to Sink?,” presentation at meeting of Northern California/Nevada section of American Association of Physics Teachers, Lawrence-Berkeley National Laboratory, Berkeley, California, 30-31 March 2001.

[7] Leonard Pringle, “Experimental Investigation of Sinking a Buoyant Body in Water with Bubbles,” M.S. Thesis, Naval Postgraduate School, June 2000.

[8] Carl DeGrace, “Sinking a Body With Bubbles in Closed and Open Environments,” M.S. Thesis, Naval Postgraduate School, December 2000.

[9] D. A. May and J. J. Monaghan, “Can a single bubble sink a ship?,” submitted to *American Journal of Physics*, 2002.

### CHICAGO'S PRAIRIE CLUB, *continued from page 19*

the Prairie Club experienced an explosion in membership and public notoriety, and a particularly prominent moment came in the Club's vigorous 1917-1930 campaign to make the Dunes a national park.

The personalities and ideas of several Prairie Club members help to characterize the group and describe its ethos. These individuals include landscape architect Jens Jensen, naturalist painter Frank Dudley, ecologist Henry Cowles, and National Parks Service founder Stephen Mather. By examining these men's varied attitudes about the Dunes and their use, we can achieve a model for the ideologies and tactics that characterized American conservation organizations. This technique is also useful in understanding the paradigm shift that the Club experienced during its national park campaign, and which eventually led to deep divisions and disunity within the organization.

<sup>1</sup> Doesrich, Emma. *Outdoors with the Prairie Club*. Chicago: Paquin Publishers, 1941, vii.



## UNDERSEA WARFARE RESEARCH CENTER, *continued from page 11*

*Environmental Influence on Shallow Water Bottom Reverberation*, Major Boon Chuan Lee, Singapore Navy (March 2002)

*Numerical Analysis of Bottom Reverberation and the Influence of Density Fluctuations*, LT Han Kao, Republic of China Navy (December 2001)

*The Effect of Sensor Performance on Safe Minefield Transit*,

LT Chihoon Kim, Republic of Korean Navy (December 2002)

*Hydrodynamics of Mine Impact Burial*, LCDR Ashley D. Evans, USN (September 2002)

*A Minefield Reconnaissance Simulator*, Mauricio Jose Machado Guede, Brazilian Navy (June 2002)

*--continued on page 43*

## THE INFLUENCE OF SHALLOW WATER VARIABILITY ON SHORT RANGE WATER BOURNE PROPAGATION

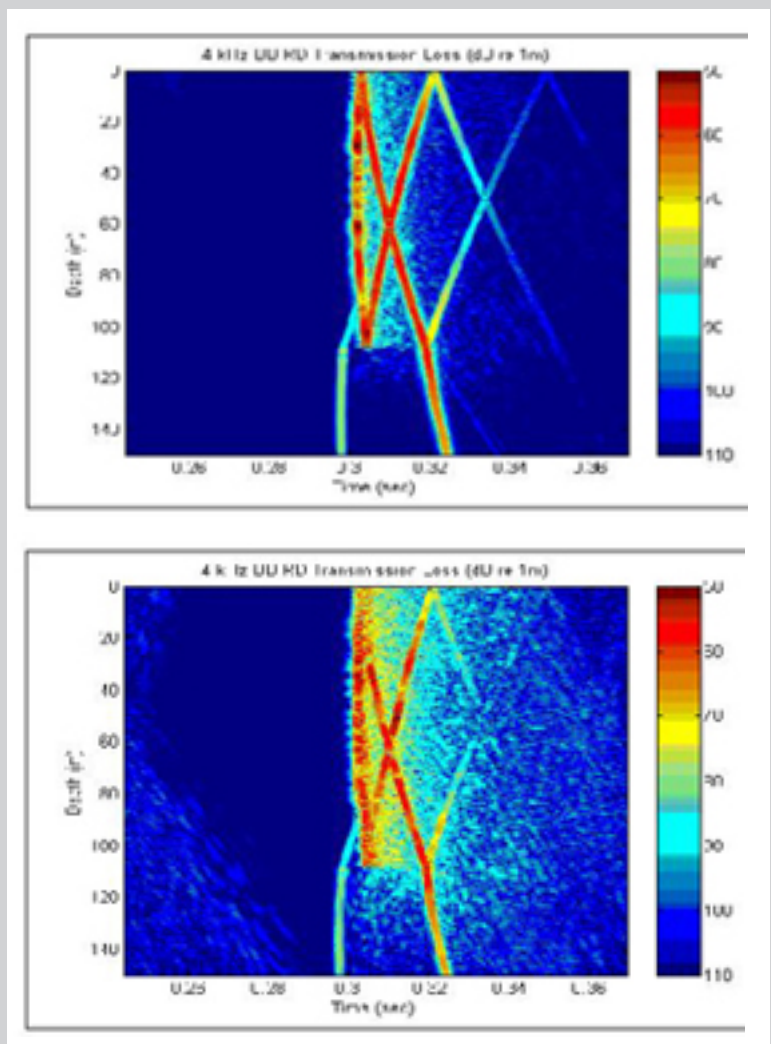
LT Stephen C. Karpi, United States Navy

Master of Science in Engineering Acoustics – December 2002

Advisors: Associate Professor Kevin B. Smith, Department of Physics, and Peter H. Dahl, Applied Physics Laboratory, University of Washington

Interest in enhancing the forecasting capabilities of both active and passive sonar systems employed in littoral regions has greatly escalated over the past 10 years. This requires a need for improvements in the general understanding of the influence of shallow water variability on acoustic propagation. This work examines the influence on the relatively short-range water-borne propagation paths of shallow water variability. Both internal wave fluctuations and random sound speed perturbations will be considered. The effects of littoral variability on acoustic propagation will be quantified in terms of spatial (vertical) coherence functions. Since the effects of the water-column variability are of interest, the direct water-borne propagation path will be solely analyzed. The data to be examined will be generated numerically based on an acoustic propagation model employing environmental data taken from the East China Sea as part of the Office of Naval Research-sponsored ASIAEX experiments.

**Predictions of broadband (2msec 4kHz pulse) acoustic propagation in shallow water with turbulent-like sound speed perturbations. The ocean bottom is at 110m. The root-mean-square level of the perturbation (upper panel) is 1m/s, and (lower panel) 5m/s. Note how the increase in perturbation level enhances the breakdown of wavefront coherence.**



# RESEARCH CENTER

## UNDERSEA WARFARE RESEARCH CENTER, *continued from page 42*

*Range Dependent Mine Hunting Using CASS-GRAB Model,*  
LT Nick A. Vares, USN (June 2002)

*Transmitting Beam Patterns of the Atlantic Bottlenose*

*Dolphin: Investigations in the Existence and Use of High Frequency Components Found in Ecolocation Signals,* LT Tobias J. Lemerande, USN (June 2002).

## BEDFORM EVOLUTION UNDER THE COMBINED INFLUENCES OF WAVES AND CURRENTS AT THE INNER-SHELF MISO SITE

ENS William C. Blodgett, Jr., United States Navy

Master of Science in Physical Oceanography – June 2002

Advisors: Research Professor Timothy Stanton and Distinguished Professor Edward B. Thornton, Department of Oceanography

Observations of the temporal evolution of waves, currents, and bed response data collected by an instrumented frame deployed in 12m of water at the Monterey Inner Shelf Observatory (MISO) off the coast of Monterey, California

are analyzed in terms of measured wave and current forcing statistics and ripple geometry. During the year 2000, a Broadband Acoustic Doppler Current Profiler (BADCP)

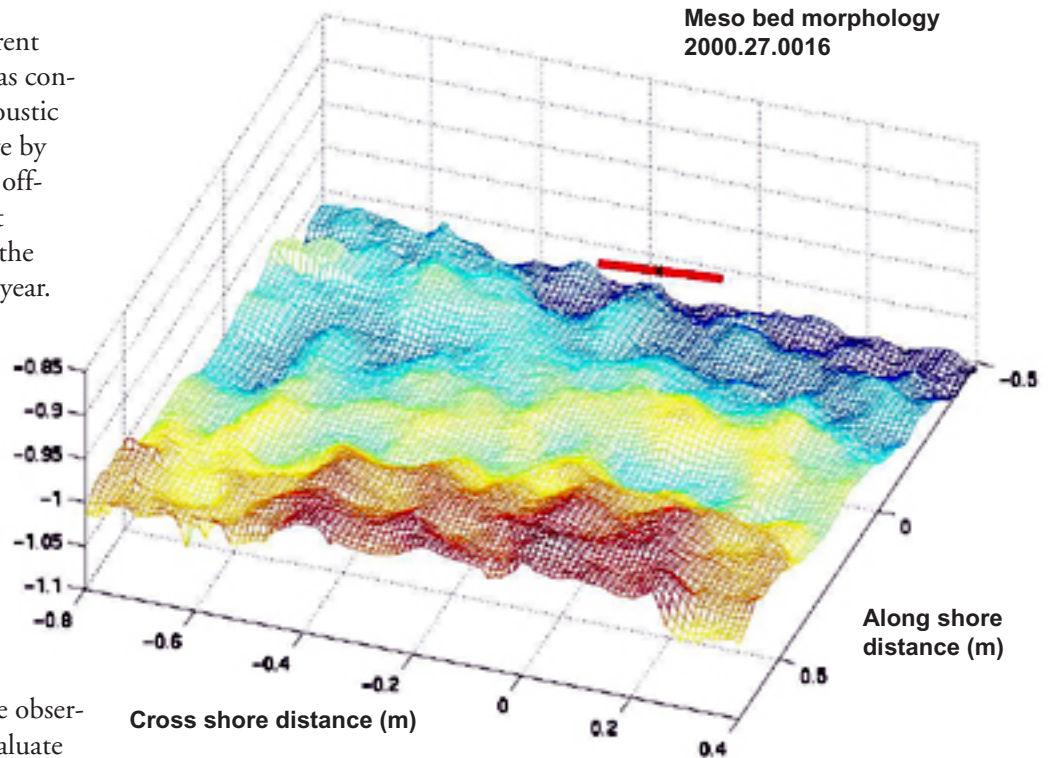
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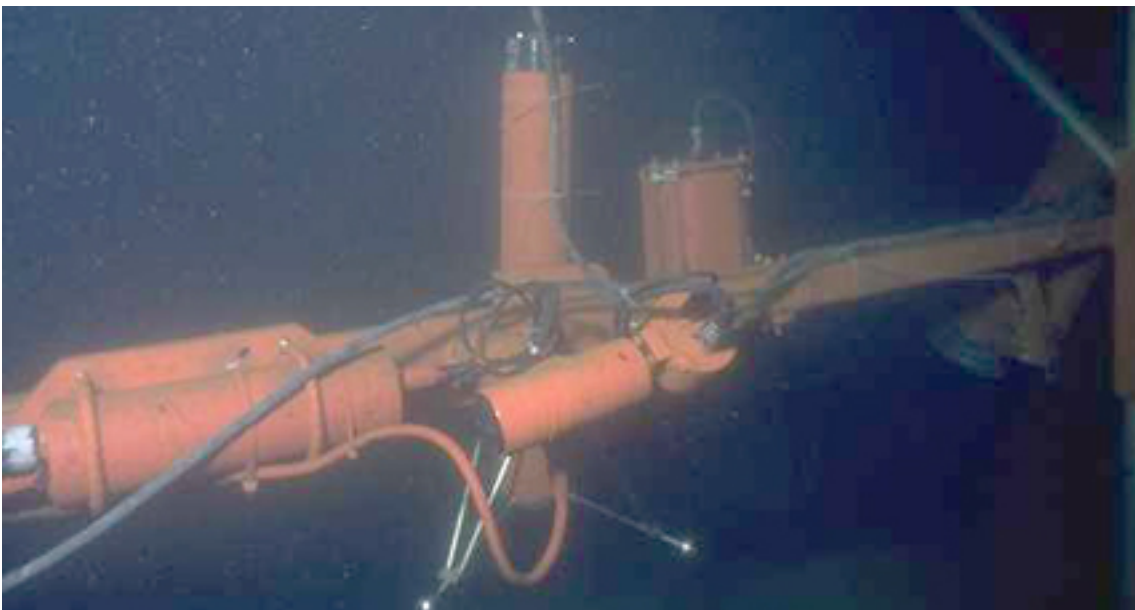
## BEDFORM EVOLUTION UNDER THE COMBINED INFLUENCES OF WAVES AND CURRENTS AT THE INNER-SHELF MISO SITE, *continued from page 43*

collected continuous wave and current measurements. Bed morphology was continually mapped by a Scanning Acoustic Altimeter (SAA) in a 1m alongshore by 1.5m cross-shore area immediately off-shore from the MISO frame. Relict ripples were observed to dominate the bedforms throughout much of the year. Ripple growth in the alongshore direction was observed during conditions of marginally critical flow as defined by the critical combined wave and current Shields parameter. As flow conditions increased above the critical level, ripple growth in the alongshore direction ceased, and cross-shore wavelengths began to grow and dominate. Together, these observations and data sets are used to evaluate the applicability of existing ripple prediction algorithms. Altogether, five models are tested, and it was concluded that they could not independently predict the bed's response.



Bedform evolution under the combined influence of waves and currents at the Inner Shelf MISO site (above).

MISO instrument frame deployed off-shore in Monterey Bay. It is cabled to shore with fiber optic data and shore power links allowing long timeseries of wave forcing and bed response to be measured over seasonal timescales. The photo specifically shows the scanned acoustic altimeter in the foreground that maps a 2-meter square of the sandy bed three times an hour, and the bistatic coherent profiler that measures velocity and turbulence profiles above the bed. Both instruments were developed at NPS (left).





# STUDENT THESES

## DECEMBER 2002 THESIS TOPICS

The thesis is the capstone achievement of the student's academic endeavor at NPS. Thesis topics address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain long-term superiority of the Navy/DoD. Listed below are the unrestricted theses topics of the December 2002 graduates. For further information, contact [research@nps.navy.mil](mailto:research@nps.navy.mil). A copy of the thesis is archived in the Dudley Knox Library and is accessible at <http://library.nps.navy.mil/uhtbin/webcat> (click on Thesis Search).

### Aeronautical and Astronautical Engineer

- Development of Precision Pointing Controllers with and without Vibration Suppression for the NPS Precision Pointing Hexapod
- Design of Optimal Cyclers Using Solar Sails
- An Improved Algebraic Grid Generator for Numerical Aerodynamic Analyses of Airfoil Cross-Sections

### Electrical Engineer

- Face Recognition Using Infrared Imaging

### Mechanical Engineer

- Tracking Control of Autonomous Underwater Vehicles

### Master of Science – Aeronautical Engineering

- Design Recovery and Implementation of the AYK-14 VHSIC Processor Module Adapter with Field Programmable Gate Array Technology

### Master of Science – Applied Physics

- High Energy Lasers for Ship-Defense and Maritime Propagation
- Active Mirror Alignment for Free Electron Lasers
- Design and First Operations of the Lineate Imaging Near-ultraviolet Spectrometer (LINUS)
- Computer-Controlled Photodetector Characterization System (Design and Construction)
- Free Electron and Solid State Lasers Development for Naval Directed Energy
- 3D Visualization of Invariant Display Strategy for Hyperspectral Imagery
- Barrel Wear Reduction in Rail Guns: An Investigation of Silver Paste Liquid-Metal Interface

### Master of Science – Astronautical Engineering

- Development of Precision Pointing Controllers With and Without Vibration Suppression for the NPS Precision Pointing Hexapod
- Development and Control of Robotic Arms for the Naval Postgraduate School Autonomous Docking Simulator (NPADS)
- Spacecraft Power Beaming and Solar Cell Annealing Using High-Energy Lasers
- Design of Optimal Cyclers Using Solar Sails Initiator Diffraction Limits for Pulse Detonation Engine Operation

### Master of Science – Computer Science

- Framework for Managing Metadata Security Tags as the Basis for Making Security Decisions
- Performance Evaluation of Voice Over Internet Protocol
- 3D Visualization of Invariant Display Strategy for Hyperspectral Imagery
- Alternate High Speed Network Access for the Last Mile
- A Methodology for the Development of Secure Vertical Web Portals

### Master of Science – Contract Management

- An Analysis of Communications between the United States Army Communications-Electronics Command (CECOM) and Industr

- Acquisition Reform through Alpha Contracting

### Master of Science – Defense Analysis

- Experimental Analysis of Integration of Tactical Unmanned Aerial Vehicles and Naval Special Warfare Operations Forces

### Master of Science – Electrical Engineering

- An Electromagnetic Interference Analysis of Uninterruptible Power Supply Systems in a Data Processing Environment
- High Energy Lasers for Ship-Defense and Maritime Propagation
- Design of a Microstrip Patch Antenna for the NPSAT1
- Performance of IEEE 802.11a Wireless LAN Standard Over Frequency-Selective, Slowly Fading Nakagami Channels in a Pulsed Jamming Environment
- Face Recognition Using Infrared Imaging
- Performance Evaluation of a Cooperative Diversity Enhanced Ad Hoc Network

- Narrowband Filtering Effects on Frequency-Hopped Signals

- Free Electron and Solid State Lasers Development for Naval Directed Energy

### Master of Science – Engineering Acoustics

- The Influence of Shallow Water Variability on Short Range Water Bourne Propagation

### Master of Science – Information Technology Management

- Measuring the Value of Graduate Information Technology Education for Marine Officers: A Proof of Concept Study

### Master of Science – Management

- Applying Department of Defense Financial Statement Guidelines to the Naval Postgraduate School
- Alternative Headquarters Support Funding for Theater Special Operations Commands
- Modeling Ship Air Conditioning Maintenance Costs Using the Integrated Condition Assessment System (ICAS)
- An Analysis of Federal Head Contracting Authority (HCA) Decisions Regarding Overrides of Statutory Stays of Contract Award and Continued Performance Resulting from Bid Protests
- Analyzing Current Multiple-Award Task Order Contracting Practices and Its Impact on Competition, Pricing and Socio-Economic Goals
- An Analysis of the Tail-to-Tooth Ratio as a Measure of Operational Readiness and Military Expenditure Efficiency
- An Analysis of the Government Commercial Purchase Card Within the United States Marine Corps
- Analysis of the Department of Defense Homeland Security Support Organization
- Sea JAVELIN: An Analysis of Naval Force Protection Alternatives
- The Performance of Reduction of Total Ownership Cost (R-TOC) Pilot Programs
- An Analysis of the Budget Formulation and Execution Process in United States Naval Dental Centers and Performance Measure Utilization in the Process
- An Economic Analysis of Acquisition Opportunities for the United States Department of Defense Within the Japanese Defense Industrial Base
- A Case Study of the Application of Reliability Centered Maintenance (RCM) in the Acquisition of the Advanced Amphibious Assault Vehicle (AAAV)
- Cost Effectiveness Analysis of the "SEA TO SWOS" Training Initiative on the Surface Warfare Officer Qualification Process
- An Analysis of the Factors Affecting the Net Operating Result at Naval

--continued on page 46

# STUDENT THESES

## DECEMBER 2002 THESIS TOPICS, *continued from page 45*

Aviation Depot Cherry Point, North Carolina Acquisition Planning for the Armed Forces of the Philippines (AFP) Modernization Program

- Two-Sided Matching for the US Navy's Enlisted Detailing Process: A Comparison of Deferred Acceptance Versus Linear Programming via Simulation
- Navy Flying Clubs: Management, Control Systems and Performance Measures
- Ten Years Worth of DoD Procurement Reforms with Specific Attention to Selected DoN Programs
- Social Factors Impacting Recruitment and Retention of the Civilian Acquisition Workforce
- Prioritization of Capital Projects
- The Evaluation of Appropriateness of OMB Circular A-76 Studies on Revenue-Generating Functions in Defense Working Capital Fund Activities
- An Analysis of Personnel Career Development Practices within the United States Marine Corps Contingency Contracting Force
- An Assessment of the IMEF Depot-level Corrosion Prevention and Control Program and the Viability of Making it More Efficient and/or Outsourcing the Requirements through Private Sector Initiatives
- An Analysis of the Requisition Process and Readiness for F/A-18E/F Integrated Readiness Support Team (FIRST) Program
- Examination of Reliability Management within the Marine Corps Acquisition Process
- Enterprise Resource Planning (ERP): A Case Study of Space and Naval Warfare Systems Center San Diego's Project Cabrillo
- A Comparative Analysis of Leadership Skills Development in Marine Corps Training and Education Programs
- The Export Administration Act of 1979 and Computer Exports to the People's Republic of China (PRC)
- An Analysis of the Common Missile and Tow 2B on the Stryker ATGM Platform, using the JANUS Simulation
- Budget Preparation, Execution and Methods at the Major Claimant/Budget Submission Office Level
- An Analysis of Electronic Commerce Acquisition Systems: Comparison of a New Pure Electronic Purchasing and Exchange System (Electronic Storefront) and Other Legacy On-Line Purchasing Systems
- An Analysis of Current and Proposed Oversight Processes for the Acquisition of Large-Scale Services as Seen Through the Eyes of the Navy Marine Corps Intranet Program
- Costs and Benefits of Using Fuel Cell for Stationary Power Generation at Marine Corps Logistics Base Barstow
- The Strategic Distribution Management Initiative and its Effects on Inventory Levels and Readiness
- The Horizon of Financial Management for the Department of Defense
- An Analysis of the Department of the Air Force, Army, and Navy Budget Offices and Budget Processes
- Analysis of For-Profit Commercial Firm Participation in Technology Investment Agreements
- Analysis of Characteristics in the Defense Supplemental Appropriations

**Master of Science – Mechanical Engineering**

- Obstacle Avoidance Control for the REMUS Autonomous Underwater Vehicle
- Motion Analysis of a Trolley Interface for Ship-to-Ship Cargo Transfer
- Tracking Control of Autonomous Underwater Vehicles
- Nonlinear Dynamics of Close Proximity Ship Towing
- A Numerical Study of Combined Convective and Radiative Heat Transfer in

a Rocket Engine Combustion Chamber

**Master of Science – Meteorology and Physical Oceanography**

- METOC and Naval Afloat Operations: Risk Management, Safety, and Readiness

**Master of Science - Oceanography**

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**Master of Science – Operations Research**

- Applying a Fix-and-Relax Heuristic to U.S. Navy Force Structure Planning
- Barrier Patrol and Air Defense System: Developing and Integrating Flight Profiles
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- A Unique Prototyping Concept for Missile and Aviation Weapon Systems
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*--continued on page 47*

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## DECEMBER 2002 THESIS TOPICS, *continued from page 46*

- Intelligence Networks and the Tri-Border Area of South America: The Dilemma of Efficiency Versus Oversight
- Building Up a Strategy for De-Balkanizing the Balkans: Stability and Prosperity in Southeastern Europe
- Master of Arts – National Security Affairs
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- The Free Trade Area of the Americas: Can Regional Economic Integration Lead to Greater Cooperation on Security
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