

Naval Postgraduate School  
Monterey, California 93943-5138

NPS-09-02-026



***SUMMARY  
OF  
RESEARCH  
2001***



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Graduate School of Engineering and Applied Sciences**

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Prepared for: Naval Postgraduate School  
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**20030709 026**

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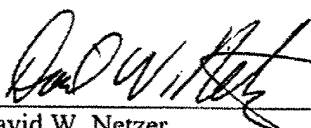
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# REPORT DOCUMENTATION PAGE

Form approved  
OMB No 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

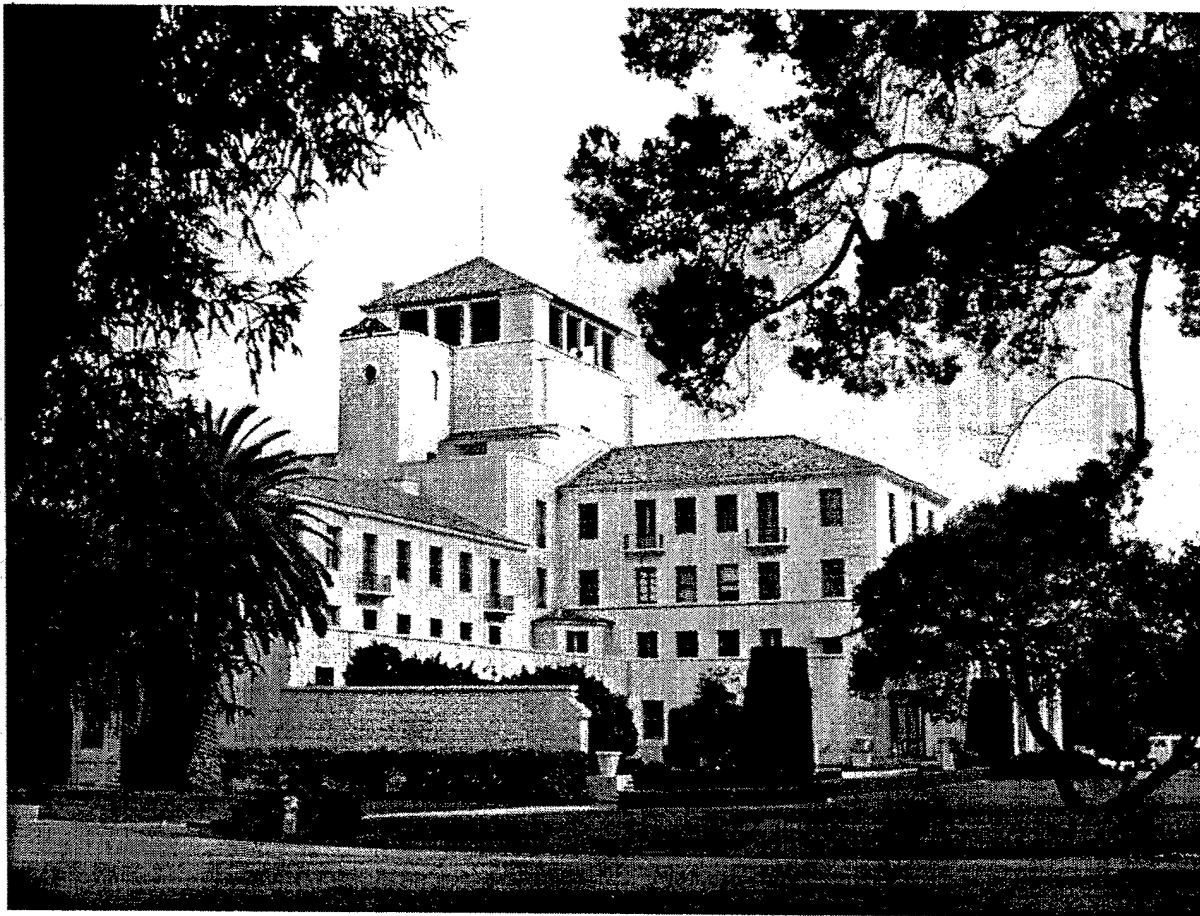
<b>1. AGENCY USE ONLY (Leave blank)</b>		<b>2. REPORT DATE</b> September 2002	<b>3. REPORT TYPE AND DATES COVERED</b> Summary Report, 1 October 2000-30 September 2001	
<b>4. TITLE AND SUBTITLE</b> Summary of Research 2001, Department of Physics			<b>5. FUNDING</b>	
<b>6. AUTHOR(S)</b> Faculty of the Naval Postgraduate School				
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> Naval Postgraduate School Monterey, CA 93943-5000			<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b> NPS-09-02-026	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> Naval Postgraduate School Monterey, CA 93943-5000			<b>10. SPONSORING/MONITORING AGENCY REPORT NUMBER</b>	
<b>11. SUPPLEMENTARY NOTES</b> The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or U.S. Government.				
<b>12a. DISTRIBUTION/AVAILABILITY STATEMENT</b> Approved for public release; distribution is unlimited			<b>12b. DISTRIBUTION CODE</b> A	
<b>13. ABSTRACT (Maximum 200 words.)</b>  This report contains project summaries of the research projects in the Department of Physics. A list of recent publications is also included, which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports. Thesis abstracts of students advised by faculty in the Department are also included.				
<b>14. SUBJECT TERMS</b>			<b>15. NUMBER OF PAGES</b> 67	
			<b>16. PRICE CODE</b>	
<b>17. SECURITY CLASSIFICATION OF REPORT</b> Unclassified	<b>18. SECURITY CLASSIFICATION OF THIS PAGE</b> Unclassified	<b>19. SECURITY CLASSIFICATION OF ABSTRACT</b> Unclassified	<b>20. LIMITATION OF ABSTRACT</b> Unlimited	

NSN 7540-01-280-5800

Standard Form 298 (Rev. 2-89)  
Prescribed by ANSI Std Z39-18

## THE NAVAL POSTGRADUATE SCHOOL MISSION

Increase the combat effectiveness of the U.S. and allied forces and enhance the security of the U.S.A. through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense related challenges of the future.



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## PREFACE

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Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Department of Physics during 2001. The summary also contains thesis abstracts for those students advised by Physics faculty during 2001.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or [research@nps.navy.mil](mailto:research@nps.navy.mil) (e-mail). Additional information is also available at the RESEARCH AT NPS website, <http://web.nps.navy.mil/~code09/>

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research:* A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research:* An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:  
<http://web.nps.navy.mil/~code09/publications.html>.

# INTRODUCTION

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The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, and maintains the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

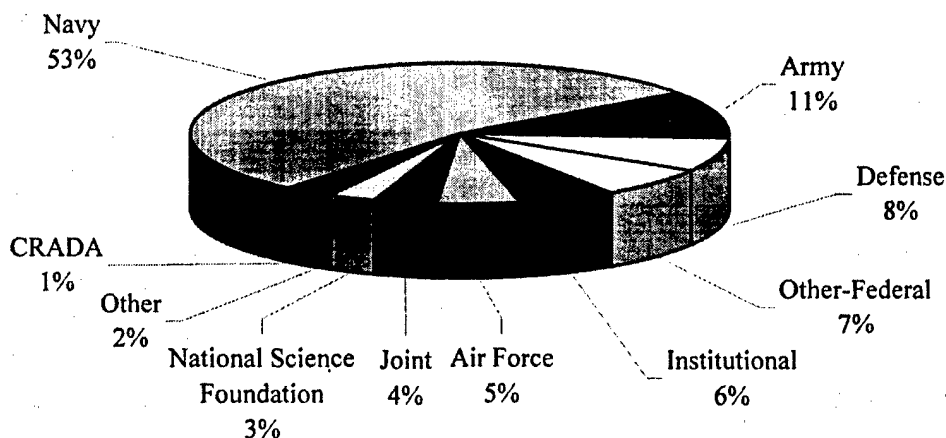
- **Reimbursable (Sponsored) Program:** This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.
- **Naval Postgraduate School Institutionally Funded Research (NIFR) Program:** The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2001, the level of research effort overall at the Naval Postgraduate School was 148 faculty work years and exceeded \$48 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2001, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2001 is provided in Figure 1.



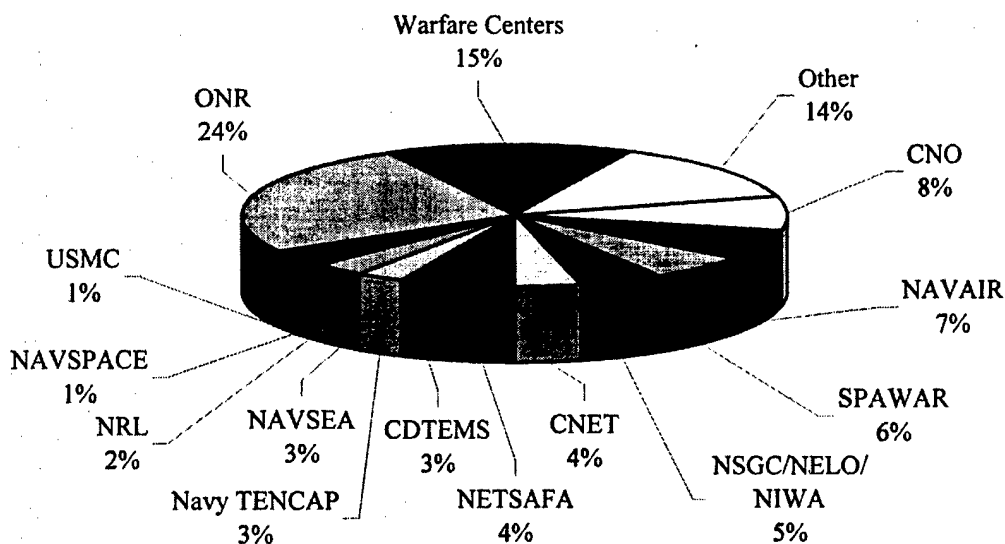
## INTRODUCTION

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**Figure 1. Profile of NPS Research and Sponsored Programs (\$52M)**

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2001 is provided in Figure 2.



**Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs (\$29M)**

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER  
Associate Provost and Dean of Research

September 2002

**DEPARTMENT OF  
PHYSICS**

**WILLIAM B. MAIER  
CHAIR**

## **DEPARTMENT SUMMARY**

---

### **OVERVIEW:**

The Department of Physics has unique resources and faculty expertise dedicated to Weapon Systems Technologies.

### **CURRICULA SERVED:**

- Combat Systems Science and Technology
- Applied Physics
- Engineering Acoustics

### **DEGREES GRANTED:**

- Master of Science in Physics
- Master of Science in Applied Physics
- Master of Science in Engineering Acoustics
- Doctor of Philosophy

### **RESEARCH THRUSTS:**

- Optical and Electromagnetic Signal Propagation, Detection and Sensor Systems
- Conventional and Nuclear Weapons and their Effects
- Underwater Acoustics
- Free Electron Laser Physics
- Physical Acoustics
- Solid State Physics

### **RESEARCH CHAIR:**

- Lawrence Livermore National Laboratory Chair Professor
- Engineering Acoustics Chair Professor

### **RESEARCH FACILITIES:**

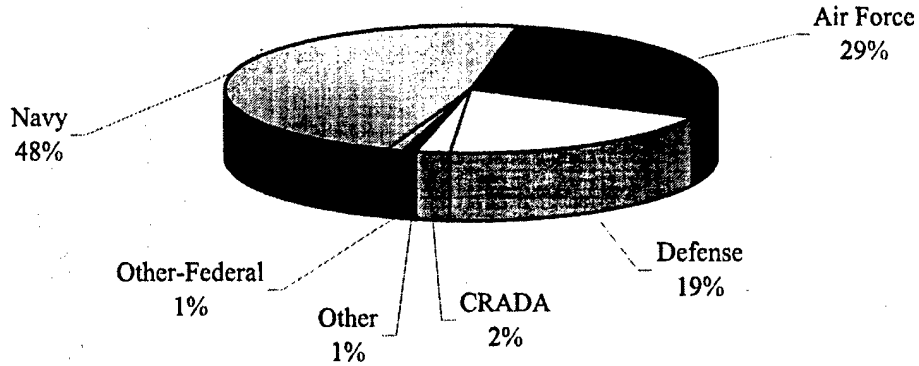
- The Physics Laboratories are equipped to carry on instruction and research work in acoustics, atomic, and molecular physics, electro-optics, spectroscopy, laser physics, computational physics, optical propagation, sensor physics and transient electrical discharges.
- The Optical Physics and Sensors Laboratory uses imaging, spectroscopic and sensing systems from far infrared to ultraviolet wavelengths, including instrumentation for seagoing, airborne and ground-based measurements.
- The Acoustics Laboratory equipment includes a large anechoic chamber, a small reverberation chamber and a multiple-unit acoustics laboratory for student experimentation in acoustics in air. Sonar equipment, test and wave tanks and instrumentation for investigation in underwater sound comprise the Underwater Acoustics Laboratory, a scale-model of a shallow water waveguide for the study of environmentally adaptive sonar and high-speed digital acoustic communication. The Physical Acoustics Laboratories are equipped with a variety of modern data collection and processing equipment.

## DEPARTMENT SUMMARY

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### RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded \$49 million in FY2001. Sponsored programs included both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Physics is provided below:



**Size of Program: \$2299K**

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## PROJECT SUMMARIES

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**BURIED MINE DETECTION**  
Steven Baker, Associate Professor  
Department of Physics  
Sponsor: Office of Naval Research

**OBJECTIVE:** Develop the technology of seismic sonar, to detect buried mines.

**DoD KEY TECHNOLOGY AREAS:** Other (Mine Countermeasures)

**KEYWORDS:** Seismic Sonar, Rayleigh Waves, Mine Detection, Surf Zone, Mine Countermeasures

**PHYSICS OF MINE DETECTION**  
Steven Baker, Associate Professor  
Thomas G. Muir, Research Professor  
Department of Physics  
Sponsor: Office of Naval Research

**OBJECTIVE:** Remotely identify buried mines against natural target echoes.

**DoD KEY TECHNOLOGY AREAS:** Other (Mine Countermeasures)

**KEYWORDS:** Mine Countermeasures, Seismic Sonar, Rayleigh Waves, Mine Detection, Surf Zone

**SEISMIC PROPAGATION AND REFLECTION IN THE SURF ZONE**  
Steven Baker, Associate Professor  
Thomas G. Muir, Research Professor  
Department of Physics  
Sponsor: Office of Naval Research

**OBJECTIVE:** Remotely discriminate manmade from natural target echoes.

**DoD KEY TECHNOLOGY AREAS:** Other (Mine Countermeasures)

**KEYWORDS:** Seismic Sonar, Rayleigh Waves, Mine Detection, Surf Zone, Mine Countermeasures

**INCORPORATING AGENT ORIENTATION IN PHYSICOMIMETICS**  
David L. Book, Visiting Professor  
Department of Physics  
Sponsor: Naval Research Laboratory

**OBJECTIVE:** Adding orientation to the agents, which will allow variation in the form of the potential well and permit the resulting global formations to be explored.

**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communication

**KEYWORDS:** Physicomimetic, Artificial Physics, Orientation, Agents, Configuration

## PROJECT SUMMARIES

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### OSCILLATORY AND RANDOMLY DRIVEN CONTRIBUTIONS TO EARLY-TIME PERTURBATION GROWTH AND RAYLEIGH-TAYLOR SEEDING ISI

David L. Book, Visiting Professor  
Department of Physics  
Sponsor: Naval Research Laboratory

**OBJECTIVE:** Add random phase variation (ISI) to the signal of the laser irradiating a target and study the behavior of a single-mode perturbation. Couple damped sonic waves to describe behavior in the shock-compressed plasma. Study role of feedout in initiating  $r_t$  on back surface of target.

**DoD KEY TECHNOLOGY AREAS:** Directed Energy Weapons

**KEYWORDS:** Rayleigh-Taylor Instability, Seeding, Laser Targets, Feedout, Random Phases

### A 100kW FREE ELECTRON LASER DESIGN

W. B. Colson, Distinguished Professor  
Department of Physics  
Sponsor: Office of Naval Research

**OBJECTIVE:** Simulation and analysis are used to develop a point design for a 100 kW average power free electron laser for ship defense.

**SUMMARY:** A system design for a high power Free Electron Laser (FEL) was developed for naval applications. The FEL design was made for a specific ship call *SEA ARCHER*, which is a small, fast carrier of the future. Also, numerical simulations were used to characterize the operation of the proposed 100 kW FEL at Thomas Jefferson National Acceleration Facility (TJNAF).

#### PUBLICATIONS:

Blau, J., Campbell, T., Colson, W.B., Ng, I., Ossenfort, W., Benson, S.V., Neil, G.R. and Shinn, M.D., "Simulations of the 100kW TJNAF FEL Using a Short Rayleigh Length," *Nuclear Instruments and Methods in Physics Research*, 2002, accepted.

Blau, J., Bouras, V., Colson, W.B., Polykandriotis, K., Kalfoutzos, A., Benson, S.V. and Neil, G.R., "Simulations of the 100kW TJNAF FEL Using a Step-Tapered Undulator," *Nuclear Instruments and Methods in Physics Research*, 2002, accepted.

Colson, W.B., "Simulations of the 100kW TJNAF FEL Using a Short Rayleigh Length," *Proceedings of the Twenty-Third International Free Electron Laser Conference*, Darmstadt, Germany, August 2001.

Colson, W.B., "Simulations of the 100kW TJNAF FEL Using a Step-Tapered Undulator," *Proceedings of the Twenty Third International Free Electron Laser Conference*, Darmstadt, Germany, August 2001.

#### PRESENTATIONS:

Colson, W.B., "Naval and FEL System Constraints," Workshop on Free-Electron Laser Development for Naval Applications, Newport News, VA, June 2001.

#### THESES DIRECTED:

Ng, I., "A Free Electron Laser Weapon For Sea Archer," Masters Thesis, Naval Postgraduate School, September 2001.



## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation, Directed Energy Weapons

**KEYWORDS:** Free Electron Laser, Directed Energy Weapons

### **HIGH POWER FREE ELECTRON LASER AT TJNAF**

**W. B. Colson, Distinguished Professor**

**Department of Physics**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** Characterize the design of the 100kW free electron laser design at Thomas Jefferson National Accelerator Facility, Newport News, VA.

**SUMMARY:** Numerical simulations were used to characterize the operation of the proposed 100 kW FEL at TJNAF. The FEL is now operating at 2kW average power, and will be upgraded to reach 10kW in the near future. After successful operation at 10kW, the system will be further upgraded to 100kW which is substantially more ambitious. Several design options were found that would not reach the 100kW goal, but some designs would reach the goal. This will help experimentalists consider only those design changes that would be most likely to succeed.

#### **PUBLICATIONS:**

Colson, W.B., "Short Wavelength Free Electron Lasers of 2001," *Twenty Third International Free Electron Laser Conference Proceedings*, Darmstadt, Germany, August 2001.

#### **PRESENTATIONS:**

Colson, W.B., "Free Electron Lasers of Today," Northern California/Nevada Section of the American Association of Physics Teachers, Monterey, CA, October 2001.

#### **THESES DIRECTED:**

Lim, L., "A Concept For CROSSBOW Mine Countermeasures and Terminal Defense Weapons," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Directed Energy Weapons

**KEYWORDS:** Free Electron Laser, Directed Energy Weapons

### **HIGH POWER FREE ELECTRON LASERS FOR SHIP DEFENSE**

**W. B. Colson, Distinguished Professor**

**Department of Physics**

**Sponsor: Naval Sea Systems Command**

**OBJECTIVE:** An informal course was prepared to teach students the systems engineering associated with the development of a directed energy FEL for naval applications.

**SUMMARY:** Students were prepared for attending the Workshop on Free-Electron Laser Development for Naval Applications, Newport News, VA (June 2001). Eight NPS students attended the workshop which lasted two days with about 100 attendees. The students were educated on the physics of free electron lasers, accelerators, power systems, cooling systems, naval space requirements, and laser beam propagation through the atmosphere.

## PROJECT SUMMARIES

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### PUBLICATIONS:

Colson, W.B., "Short Wavelength Free Electron Lasers of 2001," *Twenty Third International Free Electron Laser Conference Proceedings*, Darmstadt, Germany, August 2001.

### THESES DIRECTED:

Polykandriotis, K., "Simulations of the Proposed TJNAF 100 kW Free Electron Laser and Comparison with TJNAF Low Power Experiments," Masters Thesis, Naval Postgraduate School, September 2001.

Ng, I., "A Free Electron Laser Weapon For Sea Archer," Masters Thesis, Naval Postgraduate School, September 2001.

Blau, J., "Multimode Simulation of Free Electron Lasers," Doctor of Philosophy Dissertation, Naval Postgraduate School, March 2002.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation, Directed Energy Weapons

**KEYWORDS:** Free Electron Laser, High Energy Laser

### TJNAF HIGH POWER FREE ELECTRON LASER RESEARCH

W. B. Colson, Distinguished Professor

Department of Physics

Sponsor: Thomas Jefferson National Accelerator Facility

**OBJECTIVE:** Simulation and theoretical analysis are used to study the high-average-power free electron laser at Thomas Jefferson National Accelerator Facility, Newport News, VA.

**SUMMARY:** Numerical simulations were used to characterize the operation of the proposed 10 kW FEL at TJNAF. The FEL is now operating at 2kW average power, and will be upgraded to reach 10 kW in the near future. Several design options were found that would not reach the goal, but some designs would reach the goal.

### PUBLICATIONS:

McGinnis, R.D., Blau, J., Colson, W.B., Massey, D., Crooker, P.P., Christodoulou, A. and Lampiris, D., "Simulations of the TJNAF 10kW Free Electron Laser," *Nuclear Instruments and Methods in Physics Research A475*, pp.178, 2001.

Christodoulou, A., Lampiris, D., Colson, W.B., Crooker, P.P., Blau, J., McGinnis, R.D., Benson, S.V., Gubeli, J.F. and Neil, G.R., "Simulations of the TJNAF FEL with Tapered and Inversely Tapered Undulators," *Nuclear Instruments and Methods in Physics Research A475*, pp.182, 2001.

Thomson Jr., R.W., Short, L.R., McGinnis, R.D., Colson, W.B., Shinn, M.D., Gubeli, J.F., Jordan, K.C., Hill, R.A., Biallas, G.H., Walker, R.L., Neil, G.R., Benson, S.V. and Yunn, B.C., "TJNAF Free Electron Laser Damage Studies," *Nuclear Instruments and Methods in Physics Research A475*, pp.625, 2001.

Colson, W.B., Todd, A. and Neil, G.R., "A High Power Free Electron Laser Using a Short Rayleigh Length," *Twenty Third International Free Electron Laser Conference Proceedings*, Darmstadt, Germany, August 2001.

### THESES DIRECTED:

Polykandriotis, K., "Simulations of the Proposed TJNAF 100 kW Free Electron Laser and Comparison with TJNAF Low Power Experiments," Masters Thesis, Naval Postgraduate School, September 2001.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Directed Energy Weapons

**KEYWORDS:** Free Electron Lasers

### INFRA-RED RESEARCH - THERMAL IMAGING MODELS

A.W. Cooper, Professor  
Department of Physics

Sponsor: Naval Postgraduate School and Naval Sea Systems Command

**OBJECTIVE:** To improve the modeling of Forward Looking InfraRed (FLIR) systems, particularly the modeling of Minimum Resolvable Temperature Difference for new-generation FLIR systems, to evaluate the potential of polarization filtering in target discrimination range improvement in FLIR imagery, and to compare Tactical Decision Aid FLIR range prediction models for potential joint service use. This project is continuing.

**SUMMARY:** A computational model constructed to examine the effect of polarization filtering on ranges for detection, recognition and identification has been shown to predict significant increase in detection/recognition range by polarization filtering under certain scenarios and environmental conditions for a generic second generation FLIR system. Various methods have been evaluated for computation of Minimum Detectable Temperature Difference (MRTD) for a generic FLIR system from tabular numerical Minimum Resolvable Temperature Difference (MRTD) data. The current and developing models of MRTD for "next" generation staring imaging systems have been tested by comparison with laboratory measurements on a Mitsubishi IR M500 imager and with a new improved Visibility-based MRTD Model (VISMODII). A numerical simulation of system MRTD (the "Virtual MRTD") developed and used for theoretical interpretation of the influence of system noise and aliasing effects due to sampling in observed image features has shown that spatial sampling effects in array imaging cannot be adequately represented by additional system noise. The existence of image degradation by aliasing below the Nyquist limit has been demonstrated.

#### PUBLICATIONS:

Celik, M., Kenter, Y., Cooper, A. and Pieper, R., "Aliasing Effects in Thermal Images of Four-bar Patterns below and above the Nyquist Limit," *Proceedings of the 35th Annual Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, CA, 4-7 November 2001.

#### THESES DIRECTED:

Reyhan, G L. "Targeting and Fire Control System Analysis of the New Turkish Attack Helicopter, The AH-1Z King Cobra," Masters Thesis, Naval Postgraduate School, March 2001.

Colpo, D.J., "Defining Minimum Detectable Temperature Difference (MDT) from Minimum Resolvable Temperature Difference (MRT) in Thermal Imaging Performance Modeling," Masters Thesis, Naval Postgraduate School, June 2001.

Celik, M., "Measurements and Modeling Enhancements for the NPS Minimum Resolvable Temperature Difference Model, VISMODII," Masters Thesis, Naval Postgraduate School, September 2001.

Kenter, Y., "The NPS Virtual Thermal Image Processing Model," Masters Thesis, Naval Postgraduate School, September 2001.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Battlespace Environments, Modeling and Simulation

**KEYWORDS:** Atmospheric Optics, Infrared Sensors, FLIR, TDA, MRT, MDT

## PROJECT SUMMARIES

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### RESEARCH IN ULTRAVIOLET MULTISPECTRAL IMAGING

D. Scott Davis, Associate Professor  
Department of Physics  
Sponsor: Defense Intelligence Agency

**OBJECTIVE:** This proposal solicits funding for the continuation of calibration and field applications of the Naval Postgraduate School Ultraviolet Imaging Spectrometer (NUVIS) and for the development of an improved, next-generation ultraviolet imagine spectrometer.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Sensors, Optics, Ultraviolet, Environmental Monitoring, Remote Sensing

### SINKING OF A BODY DUE TO BUBBLES

Bruce Denardo, Associate Professor  
Department of Physics  
Sponsor: Naval Postgraduate School Research Initiation Program

**OBJECTIVES:** A body floats in a fluid when its average density is less than the density of the fluid. If gas bubbles are introduced into a liquid, the average density of the resultant fluid is reduced. If this new density is less than that of the body, then one might think that the body would sink. However, the bubbles also produce upward forces on the body, due to drag produced by the entrained flows in the fluid, and bubbles sticking to the body. It is thus not obvious whether the introduction of the bubbles can cause a floating body to sink, or, if sinking does occur, what the value of the average fluid density is required relative to the density of the body. Further uncertainty exists due to the substantial amount of turbulence that would occur. This possible sinking effect has been suggested as the cause of the demise of some ships. Large deposits of methane gas under the ocean floor could erupt and the resultant bubbles might sink a ship on the surface. Our objective was to measure the average fluid density required to sink a body, and to compare this to the average density of the body for different values of this density. This is necessary if a reliable prediction is to be made regarding the amount of bubbles that a ship can tolerate before sinking. Of future interest is the effect of bubbles on reducing the buoyant force on submerged bodies such as submarines and divers.

**SUMMARY:** In the third year of this project, publishable data was finally obtained in experiments that accurately measured the critical average fluid density of bubbly water required to barely sink a spherical body. The average density of the body was varied from 0.99 to 0.75 the density of water. Bubbles were generated over the entire cross section of the water column, which we refer to as a *closed* environment. Our theory assumes a "shadow" region directly above the body where there are no bubbles, and neglects any drag or other possible forces other than static buoyancy. The experimental data are in reasonable agreement with the theory for low airflow rates. At greater airflow rates, the experimental average fluid density is less than the predicted value, which may be due to bubbles entering the shadow region as a result of turbulence. Bubbles were also investigated in an *open* environment, which more accurately models the situation in an ocean. In this case, there was expected to be a much greater upward drag force on the body due to circulatory flow. However, the preliminary experiments indicated that this is not true. Further investigations are needed to resolve this.

**DoD KEY TECHNOLOGY AREAS:** Other (Fluid Dynamics)

**KEYWORDS:** Fluid Density, Gas Bubbles, Bubbly Water

## PROJECT SUMMARIES

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### DEVELOPMENT OF HIGH-PRESSURE MINIATURIZED THERMOACOUSTIC REFRIGERATION PROTOTYPE

Thomas J. Hofler, Associate Professor

Department of Physics

Sponsor: Rockwell Science Center

**OBJECTIVE:** The technical objective of this project is the fabrication of a miniaturized Thermoacoustic Refrigeration (TAR) device compatible with operation at elevated pressures. To enable this evaluation, the Naval Postgraduate School (NPS) will build in accordance with Rockwell Science Center (RSC) specifications and deliver to RSC a functional miniature TAR prototype capable of operating at elevated pressures. RSC is pursuing separate R&D activities complementary to the proposed work, and the elevated-pressure prototype will be used by RSC for comparison with the results of alternative research and development efforts being pursued by RSC, to provide quantitative technical information on potential future paths for performance enhancement.

**DoD KEY TECHNOLOGY AREAS:** Other (Thermo-Acoustics)

**KEYWORDS:** Miniaturized Thermoacoustic Refrigeration

### REMOTE IDENTIFICATION OF EXPLOSIVES

LCDR Daphne Kapolka, USN, Assistant Professor

Department of Physics

Sponsor: Unfunded

**OBJECTIVE:** To explore current and future capabilities for the remote detection of explosives in support of force protection.

**SUMMARY:** The October 2000 attack on the *USS COLE* underscored the need for force protection from asymmetric threats carrying high energy conventional explosives. In this project, the feasibility of the remote detection of explosives in support of force protection is examined. A draft Mission Needs Statement (MNS) and a Concept Exploration of the most promising technologies and means of employment are included in the report. Based on figures obtained from landmine flux rates, rough estimates of the concentration of TNT vapor expected downwind from a source are calculated based on atmospheric dispersion and diffusion models. The vapor concentration expected from a sample of TNT with a surface area of 1000 cm<sup>2</sup> at 21-23°C is estimated to fall to as low as 10<sup>-18</sup> mol/cc within one meter of the source. Due to the extreme drop-off in concentration with range, sensors are envisioned to be deployed on Micro Unmanned Aerial Vehicles (MAV) for transport to suspect boats. Eight sensor types were examined for their potential in meeting this detection challenge. Chemiresistor and fluorescent polymer detectors, nuclear quadrupole resonance, ion mobility spectroscopy, infrared/ultraviolet/visible spectroscopy, gas chromatography combined with surface acoustic wave sensors, and the Jaycor spectrophone were evaluated for both current capability and the potential for improvements. None of the sensors currently available are able to detect explosive vapors remotely at the concentrations expected. However, the polymer-based microchip sensors are judged to show the most promise for both increased detection limits and miniaturization. Such microchip sensors could be mounted on a MAV for transport to a suspect boat. For truly remote detection, the most promising technology examined was the Differential Absorption LIDAR (DIAL) method. This method seeks to cancel out the background noise through a differential measurement of the atmospheric absorption in a range of precise frequencies of laser light. Further research is recommended to more precisely quantify the concentrations of explosive vapors expected and to determine the potential for increased sensitivity in each of the sensor types.

#### PUBLICATIONS:

Colpo, D.J., Ferguson, K.L., O'Malley, S.P., Rutherford, S.M., Stetson, S.W., Varnedore, P. and Kapolka, D., "Remote Identification of Explosives (RIDEX), Mission Need and Concept Exploration," Naval Postgraduate School Technical Report, NPS-PH-01-003PR, August 2001.

## PROJECT SUMMARIES

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**DoD TECHNOLOGY AREA:** Other (Force Protection)

**KEYWORDS:** Explosive Detection, Asymmetric Threat, TNT, Conventional High Energy Explosives, Trace Gas Detection

### OPTICAL SENSORS OPERATING SIMILAR TO BIOLOGICAL VISION SYSTEMS

**Gamani Karunasiri, Associate Professor**

**Department of Physics**

**Sponsor: Naval Postgraduate School Research Initiation Program**

**OBJECTIVE:** The objective of the proposed research is to investigate novel sensor concepts using multi-layer semiconductor structures.

**SUMMARY:** A multi-layer semiconductor device was successfully developed to convert incident light to a series of large voltage pulses. The frequency of the pulsed was found to be proportional to the intensity of the incident light. The generation of pulses using the multi-layer device was simulated using PSPICE to optimize the device parameters. A patent application has been filled based on the initial findings. In addition, experimental studies were also carried out to probe the optical transitions in quantum well and quantum dot structures and a dual-band quantum well detector structure has been designed for the application in laser-guided weapons.

#### PUBLICATIONS:

Zhou, L., Karunasiri, G. and Chee, Y.H., "Measurement of Excited State Position of Bound-to-Bound Quantum Well Infrared Detectors," *Journal of Applied Physics*, Vol. 90, pp. 2045-2047, 2001.

Teo, K.L., Qin, L., Noordin, I.M., Karunasiri, G., Shen, Z.X., Schmidt, O.G., Eberl, K. and Queisser, H.J., "Effects of Hydrostatic Pressure on Raman Scattering in Ge Quantum Dots," *Physics Review, B*, Vol. 63, pp. 1-4, 2001.

Mei, T. and Karunasiri, G., "Investigation on Two-color Detection using Asymmetric InGaAs/GaAs/AlGaAs Multiquantum Wells with Superlattice Barriers," Asia-Pacific Optical and Wireless Communications Conference, Beijing, China, 11-15 November 2001.

Qian, X., Xu, Y.P. and Karunasiri, G., "A Tunable Bias-heating Cancellation Circuit for Microbolometer Readout Electronics," Sicon'01 Sensors for Industry Conference, Rosemount, IL, 5-7 November 2001.

Zhou, L., Akkipeddi, R., Cheah, C.W. and Karunasiri, G., "Diffraction Grating for Middle Wavelength and Long Wavelength Quantum Well Infrared Detectors," International Conference on Materials for Advanced Technologies, Singapore, 1-6 July 2001.

Ng, M.W., Chee, Y.H., Karunasiri, G. and Xu, Y.P., "On-Chip Compensation of Dark Current in Infrared Focal Plane Arrays," 2001 IEEE International Symposium on Circuits and Systems (ISCAS'2001), Sydney, Australia, 6-9 May 2001.

#### PRESENTATIONS:

Cheah, C.W., Tan, L.S., Zhou, L.F. and Karunasiri, G., "Experimental Measurement of Intersubband Transitions in GaAs/InGaAs/AlGaAs Step Multiple Quantum Wells and Comparison with Theory," Sixth International Conference on Intersubband Transitions in Quantum Wells, Asilomar, CA, 10-14 September 2001.

## PROJECT SUMMARIES

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### PATENTS:

Karunasiri, G., "Artificial Neuron Using Semiconductor Controlled Rectifier," Naval Postgraduate School, 2001, submitted.

### THESIS DIRECTED:

Stetson, S.W., "PSPICE Modeling and Parametric Study of Microbolometer Thermal Detectors," Masters Thesis, Naval Postgraduate School, June 2001.

**DoD KEY TECHNOLOGY AREA:** Sensors, Electronic Warfare

**KEYWORDS:** Photoreceptors, Biological, Multi-Color IR Sensors, Quantum Well Detectors

### LASER PLASMA RADIATION SOURCE DEVELOPMENT

William L. Kruer, Professor

William B. Maier, Senior Lecturer

Department of Physics

Sponsor: Defense Threat Reduction Agency

**OBJECTIVE:** The overall objective of this program is the continuation of a multi-year effort to perform a series of laser-plasma experiments and calculations designed to develop laser-plasma x-ray source for NWET. The Naval Postgraduate School's (NPS) collaboration with the University of California, Los Angeles (UCLA) Physics Department will design, model and evaluate the ability of multiple frequency laser light to generate abundant hot x-rays for simulating and stimulating various nuclear weapons related effects.

**DoD KEY TECHNOLOGY AREAS:** Other (Nuclear Weapons)

**KEYWORDS:** Lasers, Plasmas, X-Ray Sources

### ENVIRONMENTALLY ADAPTIVE SONAR TECHNOLOGIES

Andrés Larraza, Associate Professor

Kevin B. Smith, Associate Professor

Department of Physics

Sponsor: Office of Naval Research

**OBJECTIVE:** To examine Navy relevant applications of the phenomenon of time-reversal acoustics. This phenomenon takes advantage of the incorporation of waveguide effects into the acoustic field to adaptively remove the influence of the environment through re-transmission of a time-reversed transmission. Considered as part of this project were enhancements to active sonar detection algorithms and underwater acoustic communication systems.

**SUMMARY:** Research topics have included time reversal acoustic applications to active sonar enhancement and underwater acoustic communications, environmentally adaptive communication techniques, and general studies of shallow water influences on communication and sonar system performance. Studies with different noise levels showed time reversal to be a very robust technique for sonar enhancement. In fact, time reversal techniques proved to enhance the sonar signal by 4 dB, at a signal to noise ratio of 0 dB. Tests of Time Reversal Approach to Communications (TRAC) against Match Environment Signaling Scheme (MESS) were conducted, indicating that the MESS approach may be more promising than the TRAC approach. Numerical analysis of source-induced Doppler effects on underwater communication have also been performed. Research included theoretical, numerical, and experimental aspects of the underwater acoustic problem. Experimental studies of full-duplex communications in a shallow water channel have been successfully conducted, showing higher data transmission rates.

## PROJECT SUMMARIES

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### PUBLICATIONS:

Heinemann, M., Larraza, A. and Smith, K. B., "Acoustic Communications in an Reverberant Environment Using Single-Channel Time-Reversal Acoustics," *Applied Physics Letters*, Vol. 80, pp. 693-695, 2002.

Smith, K.B., "Computing the Influence of Doppler due to Source/Receiver Motion in Parabolic Equation Models," *Journal of Computational Acoustics*, (accepted).

Smith, K.B., Larraza, A. and Kayali, B., "Scale Model Analysis of Full-Duplex Communications in an Underwater Acoustic Channel," *Proceedings of Oceans 2001 Conference*, Honolulu, HI, 5-8 November 2001.

M. Heinemann, A. Larraza and K. B. Smith, "Experimental Studies of Applications of Time-Reversal Acoustics to Non-Coherent Underwater Communications," *Journal of the Acoustical Society of America*, submitted.

Smith, K.B., Abrantes, A.A.M. and Larraza, A., "Examination of Time-Reversal Acoustics in Shallow Water and Applications to Noncoherent Underwater Acoustic Communications," *Journal of the Acoustical Society of America*, submitted.

### PRESENTATIONS:

Larraza, A. and Smith, K., "Time Reversal Acoustics, Sonar and Acomms Applications Demonstrated in Tank Scale Experiments," ONR Peer-Review, San Diego, CA, 12-13 June 2001.

Larraza, A., "Applications of Time-Reversal Acoustics to Mine Warfare, Sonar Technology, and Underwater Acoustic Communications," Stanford University, 31 July 2001.

Larraza, A., "Tank-Scale Experiments on Applications to Time-Reversal Acoustics," Workshop on Inverse Problems and Applications, Mathematical Science Research Institute, Berkeley, CA, 14-15 November 2001.

### THESES DIRECTED:

Athanasiou, C., "Evaluation of Alternative Communication Schemes Using Environmentally Adaptive Algorithms," Masters Thesis, Naval Postgraduate School, June 2001.

Houdeshell, J., "Analysis of Optimal Operating Parameters for Shallow Water Acoustic Communications," Masters Thesis, Naval Postgraduate School, March 2001.

Stokely, J., "Experimental Studies of Two-Way Single Element Time Reversal in a Noisy Waveguide," Masters Thesis, Naval Postgraduate School, June 2001

**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications, Computing and Software, Modeling and Simulation

**KEYWORDS:** Underwater Acoustic Communication, Littoral Environments, Time-Reversal Acoustics

### TARGETING ACCURACY FOR NIIR SYSTEMS

Andrés Larraza, Associate Professor

Department of Physics

Sponsor: Navy Tactical Exploitation of National Capabilities (TENCAP) Office

**OBJECTIVE:** Non-imaging Infrared (NIIR) systems are a primary tool in the area of missile defense and related technologies. One ongoing problem has been the pointing accuracy of such systems, and in



## PROJECT SUMMARIES

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particular geolocation of small (often sub-pixel) targets. A proposed approach to this problem is to place a laser beacon in-scene as a reference. Such a device has been constructed, and work is underway to test the technology.

**SUMMARY:** The laser beacon prototype (LBP) development effort has to date occurred over a roughly four year period, including design, manufacture, integration, and deployment into a stressing field environment for testing. The LBP design includes an optical parametric oscillator, integrated pointing optics, and associated support equipment. The tracking system of the LBP has shown two main problems: (1) An inability to track a slow moving target without feedback. There was typically a complete loss of alignment in about 2 minutes. (2) Alignment repeatability problems. The LBP was realigned to match a test sequence, with realignments occurring at 5 to 30 minute intervals. The required adjustments were nearly random between tests. The LBP has been transferred to NPS from Raytheon in order to address these problems. NPS diagnosed the cause for these symptoms (by conducting alignment tests on the gimbal, the software tracking routines, and the laser), and provided solutions that can be implemented in future software designs.

### **THESES DIRECTED:**

Herrmann, C., "Targeting Accuracy for Non-Imaging Infrared Systems," Diplomarbeit Im Fach Mess-Und Informationstechnik, Universität der Bundeswehr Hamburg, April 2001.

**DoD KEY TECHNOLOGY AREAS:** Remote Sensing

**KEYWORDS:** Non-Imaging, Infrared, Satellite Illumination, Tracking

### **THERMODYNAMICS OF INFORMATION FOR THE DISA/NSA JOINT THERMONATOR PROJECT**

**James H. Luscombe, Professor**

**Department of Physics**

**Sponsor: Defense Information Systems Agency**

**OBJECTIVE:** Identify state spaces with special focus on relevance to the warfighter. Develop associated processes and software. Initial data collection. Use existing solutions from statistical PHSIS to analyze and understand networks thermodynamic signal and correlation of equilibrium and nonequilibrium fluctuations with normal and anomolous traffic. Investigate and verify degree of theoretical and mathematical similarity between the state space dynamics of information systems and physical systems. Streamline procedures for rapid identification of traffic anomalies using existing statistical physical techniques, deliveries.

**DoD KEY TECHNOLGY AREAS:** Computing and Software

**KEYWORDS:** Information Systems, Physical Systems

### **STUDY OF SEISMIC SONAR DEMONSTRATIONS FOR THE DETECTION OF BURIED MINES IN AMPHIBIOUS WARFARE SCENARIOS**

**Thomas G. Muir, Research Professor**

**Department of Physics**

**Sponsor: Office of Naval Research**

**OBJECTIVE:** Prepare seismic sonar technology for the projection of Naval power ashore.

**DoD KEY TECHNOLOGY AREAS:** Other (Mine Countermcaasures)

**KEYWORDS:** Seismic Sonar, Rayleigh Waves, Mine Detection, Mine Avoidance, Mine Clearance

## PROJECT SUMMARIES

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### ADVANCED SENSOR RESEARCH-SPECTRAL/TEMPORAL APPLICATIONS

**R. Chris Olsen, Associate Professor**  
**Department of Physics**  
**Sponsor: National Reconnaissance Office**

**OBJECTIVE:** The proposed effort is to support the NRO in MASINT research and development efforts, particularly in the area of high frame rate systems.

**SUMMARY:** Analysis was completed on multi-system fusion, and high accuracy rates were obtained in scene classification.

#### **THESIS DIRECTED:**

Alfieri, J., "Terrain Categorization Using Multitemporal Infrared Imagery," Masters Thesis, Naval Postgraduate School, June 2001.

**DoD KEY TECHNOLOGY AREAS:** Other (Remote Sensing)

**KEYWORDS:** Environmental Monitoring, Remote Sensing

### CENTRAL MASINT ORGANIZATION R&D TECHNICAL ASSISTANCE

**R. Chris Olsen, Associate Professor**  
**Department of Physics**  
**Sponsor: Defense Intelligence Agency**

**OBJECTIVE:** The proposed effort is to support the Central MASINT organization in its research and development efforts, particularly in the area of spectral imagery and high frame rate non-imaging infrared systems. Technical development of the Cobra Brass F System, exploitation of Cobra Brass F data and development of a UV spectral imager are supported.

**SUMMARY:** Significant progress was made with the Cobra Brass studies, including work in target tracking and aerosol discrimination. Work on a new UV spectrometer was begun. A two-day workshop was held on the problem of detecting chemical and biological agents.

**DoD KEY TECHNOLOGY AREAS:** Other (Remote Sensing)

**KEYWORDS:** Environmental Monitoring, Remote Sensing

### RADIANT BRASS EXPLOITATION

**R. Chris Olsen, Associate Professor**  
**Philip L. Walker, Research Associate Professor**  
**Department of Physics**  
**Sponsor: Measurements and Signal Intelligence Office**

**OBJECTIVE:** The objective is to construct and validate algorithms for using a DoD satellite (DoDSat) to predict EO performance in the desert. Two algorithms were in mind. The first is to apply an algorithm developed previously for use with AVHRR that relies on loss of contrast between light and dark areas. The second approach is to adapt to DoDSat an algorithm developed for the NASA MISR sensor. MISR photographs a ground site from several angles as it passes over it. Differing ground contrast per slant path is used to extract atmospheric optical depth. DoDSat will also achieve slant path variation due to its orbital motion. The advantage of the MISR algorithm is that inherent ground albedo may not need to be known in advance.

## PROJECT SUMMARIES

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**SUMMARY:** This project was funded for \$100K starting 1 May 2001. This project will be completed FY 02. We have collected 20 DoDSat shots of the Naval Air Warfare Center, China Lake, California coincident with times at which our ground equipment was working. Several of those images were double-angle shots taken from slightly different locations in the satellite orbit. The ground equipment is located in the Indian Wells Valley several miles from the Naval Air Station at China Lake. The equipment has been kept operational 80% of the time this past year. This high coverage allows us to ground-truth AVHRR, the MISR sensor on Terra and other NASA satellite-derived optical depths yielding indirect comparisons with DoDSat. There are also two shots of NAS Fallon, Nevada taken nearly coincident with FLIR range data obtained using a CIRPAS Altus UAV. Extinction measurements obtained from DoDSat are used as input to the TAWS FLIR code for comparison of satellite computed and measured FLIR performance.

The atmospheric optical depth retrieval algorithm developed by Professor Durkee (NPS Meteorology Department) for AVHRR is being applied to DoDSat. DoDSat retrieved optical depths are validated using ground-based measurements from the site at China Lake. The China Lake instruments are operated continuously (24x7) obviating the need for coordination with satellite over-flights. Ground data has been collected for over a year and the investigators plan to continue doing so until the end of FY 2002. This will allow ground-truth more satellite retrievals including, possibly, more DoDSat measurements. More double angle measurements are desired, but otherwise have a workable amount of data in hand. There is also an interest in the MISR retrievals, which are available on the Web, because they use a completely different algorithm than that used for AVHRR/ DoDSat retrievals; thereby, providing a cross-check.

Extinction is the quantity needed for predicting FLIR performance. Extinction is found by dividing satellite-derived optical depth by the height of the atmospheric mixing layer. This height can be obtained from radiosonde balloons, when they are available, or artificial radiosonde profiles obtained from Numerical Weather Prediction (NWP) codes. In practice, for locations where radiosonde data are not available NWP programs are the only way to get radiosonde profiles. Artificial radiosonde profiles are generated with the MM5 NWP code. These profiles are basically interpolations between radiosonde data obtained from irregular launches made at from China Lake; whereas, radiosonde profiles must be generated completely artificially at NAS Fallon, Nevada. In collaboration with CIRPAS we have collected some simultaneous DoDSat and FLIR range detection data using their Altus UAV at NAS Fallon yielding the direct measure of actual and satellite predicted FLIR performance that we seek. An alternate way to obtain the thickness of the haze layer is by estimating its temperature. It might be possible to make this estimate using the mid-wave band.

In collaboration with China Lake a "Multi-Filter Rotating Shadow Band Radiometer," MFR-7 and three aerosol sizers are operated at China Lake. The MFR-7 directly measures the optical depth of the atmosphere from ground to space providing an almost direct band-for-band comparison with DoDSat-derived optical depths in the coincident parts of their response spectra. Aerosol size measurements from the three particle sizers along with Mie calculations are used to extend the spectral comparison. NAWC also shares data from two nephelometers and other air quality instruments and meteorology instruments providing. The MFR-7 and sizer data are transmitted to NPS periodically. Other data are supplied to NPS quarterly via a contractor.

### **PUBLICATION:**

Walker, P. and Blomshield, F., "Optical Characteristics of Desert Dust," *Proceedings of SPIE*, Vol. 4718, Orlando, FL, April 2002.

### **DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Environment, Transmission

## PROJECT SUMMARIES

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### RESEARCH IN SPECTRAL TEMPORAL IMAGING

**R. Chris Olsen, Associate Professor**  
**Department of Physics**  
**Sponsor: National Reconnaissance Office**

**OBJECTIVE:** The proposed research is in the development of spectral, polarimetric and high temporal resolution systems. Exploitation of NTM data is supported, along with exploitation of NIIR data.

**SUMMARY:** Analysis was completed on multi-system fusion, and high accuracy rates were obtained in scene classification.

#### **THESIS DIRECTED:**

Reese, J., "Terrain Categorization Using Multitemporal Synthetic Aperture Radar (SAR)," Masters Thesis, Naval Postgraduate School, June 2001.

**DoD KEY TECHNOLOGY AREAS:** Other (Remote Sensing)

**KEYWORDS:** Environmental Monitoring, Remote Sensing

### TERRAIN CATEGORIZATION VIA SENSOR FUSION

**R. Chris Olsen, Associate Professor**  
**Department of Physics**  
**Sponsor: National Reconnaissance Office**

**OBJECTIVE:** The proposed research is to study the utility of data from national technical means (NTM) for terrain categorization (TERCAT). Data from visible, IR and radar systems have been acquired in modes available to operational users, and will be analyzed according to the techniques currently in use for the interpretation of spectral imagery.

**SUMMARY:** Analysis was initiated on a project exploiting NTM for the problem of Naval Order of Battle (NOB). The primary purpose is to support the counter-drug efforts at JIATF-East. Data analysis procedures were begun.

**DoD KEY TECHNOLOGY AREAS:** Other (Remote Sensing)

**KEYWORDS:** Environmental Monitoring, Remote Sensing

### REVERBERATION MODELING AND DATA ANALYSIS IN ASIAEX

**Kevin B. Smith, Associate Professor**  
**Department of Physics**  
**Sponsor: Office of Naval Research**

**OBJECTIVE:** The objective of this research was to model the influence of propagation on both interface and volume reverberation over a large bandwidth of frequencies, examine the spatial correlations of the predicted reverberant signal, and compare such predictions with data collected in the ASIAEX experiments. By understanding the role of the acoustic propagation in such signals, a more clear description of the underlying dominant scattering mechanisms should emerge. This may also provide important information on the statistics of the signal, enhancing the use of active systems by accounting for some of the reverberation structure in the signal processing.

**SUMMARY:** The theoretical development of the PE reverberation model was expanded to incorporate density fluctuations in the sediment volume. Both interface roughness and sediment sound speed and density fluctuations were computed based on characteristic spectral models of such perturbations. These

## PROJECT SUMMARIES

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were incorporated into the PE model, and solutions of the acoustic propagation for both CW and broadband pulse sources were generated. During this development portion, only a single realization for both the interface and volume fluctuations was used in order to concentrate on the processing algorithms. The rms fluctuation of the interface was set to 1m while the volume sound speed rms fluctuation was fixed at 15m/s. The density perturbations scaled appropriately with sound speed fluctuations. Both interface and volume perturbations were included in all calculations, although the reverberation due to each was considered separately. Thus, it is possible that one type of perturbation may dominate the structure of both types of reverberation.

From both CW and broadband calculations, vertical spatial correlations of the reverberation field were computed. Additionally, the statistical characteristics of the reverberation signal were examined. It was found that the introduction of density fluctuations decreased returns from long range due to the resultant additional forward scattering. However, the structures of the returns remained very similar, due to the correlation between sound speed and density perturbations in the volume. It was also found that the vertical structure of the signals was less coherent for the volume returns than for the interface. Further examination of this effect will occur in FY02. Spectral analysis of the signals did not reveal any apparent relationships between the perturbations and the reverberation structure. This will also be investigated further in the future.

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Smith, K.B., Li, L.-S., Lee, B.-C. and Kao, H., "Sediment Interface and Volume Reverberation Modeling with The Parabolic Approximation," *Journal of the Acoustical Society of America*, Vol. 110, pp. 2743, 2001.

### **THESIS DIRECTED:**

Kao, H., "Numerical Analysis of Bottom Reverberation and the Influence of Density Fluctuations," Masters Thesis, Naval Postgraduate School, December 2001.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation

**KEYWORDS:** Shallow Water Reverberation, Parabolic Equation Modeling

**DEPARTMENT OF  
PHYSICS**

**2001  
Faculty Publications  
and Presentations**

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Ng, M.W., Chee, Y.H., Karunasiri, G. and Xu, Y.P., "On-Chip Compensation of Dark Current in Infrared Focal Plane Arrays," 2001 IEEE International Symposium on Circuits and Systems (ISCAS '2001), Sydney, Australia, 6-9 May 2001.

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Zhou, L., Akkipeddi, R., Cheah, C.W. and Karunasiri, G., "Diffraction Grating for Middle Wavelength and Long Wavelength Quantum Well Infrared Detectors," International Conference on Materials for Advanced Technologies, Singapore, 1-6 July 2001.

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Colson, W.B., "Simulations of the 100kW TJNAG FEL Using a Step-Tapered Undulator," Twenty Third International Free Electron Laser Conference, Darmstadt, Germany, August 2001.



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### **PATENTS**

Karunasiri, G., "Artificial Neuron Using Semiconductor Controlled Rectifier," Naval Postgraduate School, 2001, submitted.

**DEPARTMENT OF  
PHYSICS**

**Thesis Abstracts**

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## THESIS ABSTRACTS

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### **TERRAIN CATEGORIZATION USING MULTITEMPORAL INFRARED IMAGERY**

**Julie M. Alfieri-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1996**

**Masters of Science in Systems Technology-June 2001**

**Advisor: Richard C. Olsen, Department of Physics**

**Second Reader: Alan A. Ross, Navy Tactical Exploitation of National Capabilities (TENCAP)  
Chair Professor**

Terrain Categorization (TERCAT) in remote sensing is used extensively by the United States Military to conduct Intelligence Preparation of the Battlefield (IPB). This thesis explores the feasibility of exploiting multitemporal infrared imagery for the purpose of TERCAT. Two littoral locations were imaged multiple times from August through October 1998 using National Technical Means (NTM). Images were merged and analyzed using commercial off the shelf (COTS) technology, producing TERCAT maps of both target areas. Both supervised and unsupervised classification methods were used in this process. The TERCAT maps were compared with ground truth measurements to determine the overall classification accuracy. Accuracy levels above eighty percent were achieved. This variation on traditional change detection methods provides an alternative single-sensor approach to terrain categorization that can be utilized by the military.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Remote Sensing, Sensor Fusion, TERCAT

### **EVALUATION OF ALTERNATIVE COMMUNICATION SCHEMES USING ENVIRONMENTALLY ADAPTIVE ALGORITHMS**

**Christos Athanasiou-Lieutenant, Hellenic Navy**

**Diploma, Hellenic Naval Academy, 1992**

**Master of Science in Applied Physics-June 2001**

**Master of Science in Electrical Engineering-June 2001**

**Advisors: Andrés Larraza, Department of Physics**

**Kevin B. Smith, Department of Physics**

**Monique P. Fargues, Department of Electrical and Computer Engineering**

Time-varying multipath propagation in a shallow underwater environment causes intersymbol interference in high-speed underwater acoustic (UWA) communications. Combating this effect is considered to be the most challenging task requiring large adaptive filters and increasing the computational burden at the receiver end.

This thesis presents results of an in-tank experiment and data analysis performed off-line to examine, evaluate, and compare the robustness of Time-Reversal Approach to Communications (TRAC) and the Matched Environment Signaling Scheme (MESS) in different conditions, such as noise, surface waves and range changes between the receiver and transmitter. Both methods examined can environmentally adapt the acoustic propagation effects of a UWA channel. The MESS method provides a communications solution with increased computational complexity at the receiver end but gives higher data rates and is more robust to the presence of noise, surface waves, and range changes than the TRAC method. On the other hand, the TRAC method manages to accomplish secure communications with low computational complexity at the receiver.

**DoD KEY TECHNOLOGY AREA:** Command, Control and Communications

**KEYWORDS:** Time Reversal Acoustics, Acoustic Communications, Acoustic Signal Processing, Acoustic Telemetry

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## THESIS ABSTRACTS

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### **PASSIVE TARGET TRACKING WITH UNCERTAIN SENSOR POSITIONS USING WAVELET-BASED TRANSIENT SIGNAL PROCESSING**

**Robert J. Barsanti-Lieutenant Commander, United State Navy**

**B.S., Polytechnic University, 1982**

**M.S., Naval Postgraduate School, 1996**

**Doctor of Philosophy in Electrical Engineering-June 2001**

**Advisor: Murali Tummala, Department of Electrical and Computer Engineering**

**Committee Members: Charles W. Therrien, Department of Electrical and Computer Engineering**

**Jovan E. Lebaric, Department of Electrical and Computer Engineering**

**Thomas Hofler, Department of Physics**

**Dr. Michael Shields, Michael Shields Inc.**

This dissertation investigates the problem of tracking a maneuvering target from passive acoustic sensors of uncertain position. A batch oriented *maximum a posteriori* (MAP) algorithm using an expanded state vector is used to accurately estimate both the sensor's location and target trajectory from the data. Three sensor motion models are developed and compared under a variety of tracking scenarios. Additional tracking improvement is achieved through the use of transient signal processing. Two new wavelet-based time difference of arrival estimation methods are developed and compared to classical techniques. Testing on a variety of transient signals demonstrates that improved performance over the classical methods is achieved. The practicality and viability of the proposed techniques is confirmed through the modification and testing of a state of the art acoustic tracking system.

**DoD KEY TECHNOLOGY AREA:** Sensors, Target Tracking

**KEYWORDS:** Target Tracking, Non-Linear Estimation, Wavelet Analysis

### **PREDICTION OF WIRELESS COMMUNICATION SYSTEMS PERFORMANCE IN INDOOR APPLICATIONS**

**Ilias Bolanis-Lieutenant, Hellenic Navy**

**B.S., Hellenic Naval Academy, 1990**

**Master of Science in Electrical Engineering-December 2000**

**Advisors: Jovan Lebaric, Department of Electrical and Computer Engineering**

**James Luscombe, Department of Physics**

Due to a shift in the interest in wireless applications, from outdoor to indoor environments, new modeling solutions had to be designed to account for the immense complexity of the latter. Essentially, two categories of indoor propagation models prevailed until the mid-90s: the empirical and the physical models. They both predicted important characteristics of a given confined environment like the coverage area, transmitted power requirements, number and location of base stations or access points. The implementation of wireless communications systems onboard naval assets is expected to offer numerous advantages and enhance the existing shipboard communications systems. That, in turn, calls for a reliable and cost-effective means of estimating the expected link budget in such environments, especially when the infrastructure in question is yet to be built, as is the case in a ship class under development.

This thesis treats the problem of indoor propagation modeling using the Numerical Electromagnetic Code-Basic Scattering Code (NEC-BSC) and compares the predicted results obtained by this code with actual measurements performed inside a building at the Naval Postgraduate School. A number of important conclusions regarding the validity of NEC-BSC for indoor applications are being reached and some intriguing statistical results are being presented.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** Simulation of Signal Propagation, Indoor Radio Propagation, NEC-BSC

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## THESIS ABSTRACTS

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### MEASUREMENTS AND MODELING ENHANCEMENTS FOR THE NPS MINIMUM RESOLVABLE TEMPERATURE DIFFERENCE MODEL, VISMODII

Mustafa Celik-First Lieutenant, Turkish Army  
B.S., Turkish War College, 1996

Master of Science in Systems Engineering-September 2001

Advisors: Ronald J. Pieper, Department of Electrical and Computer Engineering  
Alfred W. Cooper, Department of Physics

Minimum Resolvable Temperature Difference (MRTD) measurement has long been used to describe the performance of thermal imaging systems. Computer models such as U.S. Army's FLIR92, that were developed to predict the MRTD, were reported to have deficiencies in dealing with sampling and aliasing effects. The models also include assumptions regarding the observer recognition process and therefore cannot predict the MRTD of an imager that incorporates an "objective" automatic target recognition device instead of a "subjective" human observer. The Visibility Model II developed for second generation thermal imaging systems at the Naval Postgraduate School (NPS) in the mid 90s takes sampling and aliasing issues into account and makes no assumptions about the observer. Modeling enhancements in VISMODII and its extension to predict objective MRTD are proposed and tested in this thesis. A parallel thesis at the NPS has shown that aliasing effects on image appearance are fundamentally different from noise. The improved VISMODII model accounts for the fact that unlike noise, aliasing may have a visual enhancing effect and therefore may lower MRTD. Experiments were conducted to measure subjective and objective MRTD. Experimental results demonstrated that the VISMODII model successfully predicts the MRTD both for the subjective and the objective schemes.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Modeling and Simulation

**KEYWORDS:** Minimum Resolvable Temperature Differences, Thermal Imaging System, MRTD, VISMODII

### SIMULATIONS OF THE TJNAF FREE ELECTRON LASER WITH A NEGATIVE TAPER AND LASER DAMAGE STUDIES

Adamantios Christodoulou-Lieutenant, Hellenic Navy  
B.S., Hellenic Naval Academy, 1990

Master of Science in Applied Physics-December 2000

Advisors: William B. Colson, Department of Physics  
Robert L. Armstead, Department of Physics

The Free Electron Laser (FEL) is a candidate for a future close-in weapon system that will provide a longer protective range for missile destruction. The FEL is also tunable to wavelengths that would give good atmospheric transmission and optimal target absorption characteristics at the target. This thesis describes single-mode and multimode simulation results of the Thomas Jefferson National Accelerator Facility (TJNAF) FEL operating at far infrared wavelengths. The TJNAF FEL uses inverse tapering and is driven by 34.5 MeV and 47.5 MeV energy electron pulses. Steady-state power, weak-field steady state gain, electron beam energy spread and optical spectrum widths were explored as a function of the desynchronization and tapering rate. The simulations described FEL pulse evolution and short pulse effects. The simulation results have been presented at an International Conference held at Duke University, Durham, NC in August 2000. In addition, the results of damage to Slip-cast Fused Silica samples by the TJNAF FEL, with and without the effect of airflow are analyzed. A comparison with older damage experiments was done in order to develop scaling rules in the future.

**DoD KEY TECHNOLOGY AREAS:** Directed Energy Weapons, Modeling and Simulation

**KEYWORDS:** Free Electron Laser, Undulator, Negative Taper, Close-in Weapon Systems

## THESIS ABSTRACTS

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### **DEFINING MINIMUM DETECTABLE TEMPERATURE DIFFERENCE (MDT) FROM MINIMUM RESOLVABLE TEMPERATURE DIFFERENCE (MRT) IN THERMAL IMAGER PERFORMANCE MODELS**

**Daniel J. Colpo-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1994**

**Master of Science in Applied Physics-June 2001**

**Advisors: Alfred W. Cooper, Department of Physics**

**Andreas K. Goroeh, Naval Research Laboratory**

Thermal Imaging System performance prediction is typically based on the summary performance parameter Minimum Resolvable Temperature Difference (MRT), the minimum temperature difference between bars and background that allows an observer to resolve a standard four-bar target. In operational systems, MRT may be available only as a tabulated data set. For detection of smaller, distant and unresolved targets, the appropriate measure may be the Minimum Detectable Temperature Difference (MDT) defined for a uniform square target against a uniform background.

This study addressed the calculation of MDT from data derived for the MRT curve. A transfer function was developed in terms of system engineering parameters for derivation of MDT from MRT and evaluated using three analytical thermal imager performance models. This method produced favorable results for spatial frequencies below the resolution cutoff limit. Beyond the resolution limit, a transfer function method using spatial frequency independent resolution parameters and a curve-fit method for measured MRT data that employs randomly selected constants were evaluated. These methods show promise for using MRT parameters to evaluate MDT beyond the cutoff and the curve-fit proved a good approximation for MDT data beyond the cutoff spatial frequency.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Modeling and Simulation

**KEYWORDS:** Thermal Imagers, Minimum Detectable Temperature Difference (MDTD), Minimum Resolvable Temperature Difference (MRTD)

### **SINKING A BODY WITH BUBBLES IN CLOSED AND OPEN ENVIRONMENTS**

**Carl W. DeGrace-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1994**

**Master of Science in Applied Physics-December 2000**

**Advisor: Bruce Denardo, Department of Physics**

**Second Reader: Ashok Gopinath, Department of Mechanical Engineering**

The presence of bubbles in a liquid decreases the average density, and thus decreases the buoyant force on a floating body. Competing with the decrease in buoyancy is an upward drag due to the bubble motion and entrained liquid. This thesis presents investigations of the critical average density required to sink a buoyant body in water with bubbles in closed and open environments. A closed environment is where bubbles fill the container, in which case there is expected to be little if any upward flow of water at the body. An open environment is where the bubbles exist over a small cross-sectional area compared to the total cross-sectional area of the container, which models the effect of a methane eruption from the ocean floor. In this case, a substantial upward flow of water is entrained in the region of the bubbles, and a downward flow consequently occurs outside this region. Experiments for both closed and open environments are reported, where the average specific gravity of the body is varied. The closed environment data significantly deviate from a quantitative theory, and the open environment data are not in accord with a qualitative theory. Possible explanations for these deviations are offered.

**DoD KEY TECHNOLOGY AREA:** Other (Fluid Dynamics)

**KEYWORDS:** Water, Density, Specific Gravity, Volume Fraction, Bubbles, Buoyancy, Nonnewtonian Fluid

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## THESIS ABSTRACTS

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### DESIGN OF A MINI THERMO-ACOUSTIC REFRIGERATOR

Seyhmus Direk-Lieutenant Junior Grade, Turkish Navy

B.A., Turkish Naval Academy, 1995

Master of Science in Engineering Acoustics-March 2001

Advisor: Thomas J. Hofler, Department of Physics

Second Reader: Richard Harkins, Department of Physics

A miniature thermoacoustic refrigerator is being developed for the purpose of cooling integrated circuits below their failure temperature when used in hot environments. The development of an electrically powered acoustic driver that powers the thermoacoustic refrigerator is described. The driver utilizes a flexural tri-laminar piezoelectric disk to generate one to two Watts of acoustic power at 4 kHz in 15 bar of He-Kr gas mixture. This thesis is the second of two driver development theses, which includes the information on the assembly of three drivers and their quantitative performance with a pressurized test resonator. A maximum acoustic power output of 0.5 Watt, was achieved with the third driver.

**DoD KEY TECHNOLOGY AREA:** Electronics

**KEYWORDS:** Thermo-acoustic Refrigerator, TAR, Thermo-acoustic Refrigerator Driver, Microchip Cooling

### OPTIMIZATION OF MULTIPLE PLATFORM PRECISION GEOLOCATION THROUGH COMPUTER SIMULATION

Kenneth L. Ferguson-Lieutenant, United States Navy

B.S., United States Naval Academy, 1993

Master of Science in Physics-June 2001

Advisors: Herschel H. Loomis, Department of Electrical and Computer Engineering

Donald L. Walters, Department of Physics

Gerry Baumgartner, Space and Naval Warfare Systems Command

The fundamental mathematical relationships that govern Time Difference of Arrival (TDOA) geolocation suggest that to reduce the positional uncertainty in the target, the baseline between the two collectors can be lengthened. A multiple-platform precision geolocation system is modeled using Operational Performance Simulation (OPS) software and tested with various baseline lengths to determine the impact on system performance.

**DoD KEY TECHNOLOGY AREAS:** Air Vehicles, Space Vehicles, Command, Control and Communications, Electronic Warfare, Sensors, Modeling and Simulation

**KEYWORDS:** Computer Simulation, Unmanned Aerial Vehicles, Precision Geolocation

### THE NPS SMALL ROBOTIC TECHNOLOGY INITIATIVE, MAN-PORTABLE ROBOTS FOR LOW INTENSITY CONFLICT

Todd W. Ferry-Captain, United States Marine Corps

B.S., United States Naval Academy, 1992

Master of Science in Applied Physics-June 2001

Advisor: Richard M. Harkins, Department of Physics

Second Reader: Thomas J. Hofler, Department of Physics

The Naval Postgraduate School's Small Robotic Technology (SMART) Initiative is an ongoing research effort within the Combat Systems Science and Technology Curriculum that engages in forward-looking applications of small robotic technology for military employment. The immediate goal of which is to develop a multipurpose robotic platform that is capable of hosting varied sensor packages for military research. This thesis successfully accomplished initial background research and integration of a low cost, lightweight, all-terrain, robotic vehicle to fulfill this requirement. The areas of robotic investigation

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included: research and procurement of a Foster Miller Lemming tracked vehicle; the selection of a robust, network enabled, real-time microcontroller called the ipEngine; selection of Differential GPS as a highly accurate autonomous vehicle positioning technique; and the development of the ipEngine software environment for integration and testing of the microcontroller's wireless interfacing. Wireless communication tests using TCP/IP sockets, serial communication, telnet and a common Internet Web Browser validated the ability to remotely operate the vehicle under both direct and autonomous control. Ultimately, this thesis laid the foundation for follow-on NPS students to research and integrate varied robotic sensing techniques, including synthetic array seismic sonar's and chemical detection devices, and to participate in cooperative research with other military laboratories.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Electronics, Sensors, Ground Vehicles, Robotics

**KEYWORDS:** Robotics, Autonomous, Micro-Controller, Embedded Processor, Differential GPS, FPGA, ipEngine, Man-portable

### TESTING AND DEVELOPMENT OF A SHROUDED GAS TURBINE ENGINE IN A FREEJET FACILITY

Hector Garcia-Lieutenant Commander, United States Navy

B.S., University of California-Riverside, 1986

Master of Science in Applied Physics-December 2000

Advisors: Garth V. Hobson, Department of Aeronautics and Astronautics

Karlheinz E. Woehler, Professor Emeritus

Testing and analysis of a shrouded turbojet engine with possible application for high speed propulsion on low cost Unmanned Combat Aerial Vehicles (UCAV), Unmanned Aerial Vehicles (UAV) and missiles was the subject of this thesis. The possibility of a turbojet providing thrust at subsonic conditions and the ramjet section providing the thrust in the supersonic regime exists. The combined cycle engine (CCE) could be incorporated into a variety of applications.

The building of a new freejet facility and engine test rig at the Naval Postgraduate School enabled dynamic testing of the ongoing development of a turboramjet. The freejet facility and new engine stand performed without exception. The shrouded engine was dynamically tested in a freejet up to Mach 0.4. The engine performance measurements closely matched those predicted by a cycle analysis program, GASTURB.

Computational fluid dynamics (CFD) was used to analyze the supersonic inlet at a design point of Mach 2. The results provided by the CFD code, OVERFLOW, matched theoretical flow parameters. The intake design was slightly modified to enhance performance of shock waves in the supersonic flight regime.

**DoD KEY TECHNOLOGY AREAS:** Aerospace Propulsion and Power, Air Vehicles

**KEYWORDS:** Micro-Turbojet, GASTURB, Engine Shroud, Turboramjet, Sophia J450, Microturbine



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## THESIS ABSTRACTS

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### **JAVA-BASED IMPLEMENTATION OF MONTEREY-MIAMI PARABOLIC EQUATION (MMPE) MODEL WITH ENHANCED VISUALIZATION AND IMPROVED METHOD OF ENVIRONMENTAL DEFINITION**

**Yonghoon Ha-Lieutenant, Republic of Korea Navy**

**B. S., ROK Naval Academy, 1994**

**B. S., Seoul National University, 1997**

**Master of Science in Engineering Acoustics-December 2000**

**Advisors: Don Brutzman, Undersea Warfare Academic Group**

**Kevin B. Smith, Department of Physics**

The Monterey-Miami Parabolic Equation (MMPE) Model is a full-wave underwater acoustic propagation model that utilizes the split-step Fourier marching algorithm. Previously the MMPE model was implemented in Fortran language and ran with a simple command line interface either in a Unix or DOS command window. After the Fortran code was run, the resulting binary data output file was post-processed using Matlab routines to extract specific field data and present the results in graphical form. This approach requires the user to have installed both Matlab and Fortran compilers. The MMPE model and associated acoustic processing tools are now rewritten in the object-oriented language Java. This new version of the MMPE model built within a Windows framework is called WinMMPE. Integrating the model, the post-processing calculations and the graphics generation together with a graphic user interface has produced a more attractive tool for users. A user-friendly, efficient, and accurate full-wave acoustic propagation model with enhanced visualization can make it easier to assess the spatial transmission loss in underwater acoustic environment.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Underwater Acoustic Propagation, Acoustic Modeling, Java, Parabolic Equation, MMPE, Winmmpe, VRML, 3D, Sonar Visualization

### **BANDWIDTH OPTIMIZATION OF UNDERWATER ACOUSTIC COMMUNICATIONS SYSTEMS**

**Jack E. Houdeshell-Lieutenant, United States Navy**

**B.S., University of Idaho, 1994**

**Master of Science in Engineering Acoustics-March 2001**

**Advisors: Kevin B. Smith, Department of Physics**

**Daniel T. Nagle, Naval Undersea Warfare Center**

Current underwater acoustic communication systems operate in the frequency band of 1-10 kHz and utilize various forms of signal processing to improve data rates. In this work, the influence of the environment on long-range propagation of acoustic signals was examined over the band of 1-5 kHz. Three methods of evaluation (transmission loss, temporal coherence, and spatial coherence) were employed.

Transmission loss (TL) has been studied for many years and was included as a fundamental measure. It can be shown that TL is related to the transmission power required for a specific signal to noise ratio required for reception. Temporal coherence relates the received pressure signals as a function of time for varying bottom roughness and source motion. Similarly, spatial coherence compares the received pressure signal as a function of frequency and of depth for varying bottom roughness and source motion. Both spatial and temporal coherence evaluate the degradation of the arrival structure.

Based on the relationships observed for transmission loss, temporal coherence, and spatial coherence, it appears that the optimization of the communications bandwidth is highly dependent on the characteristics of the environment. In this study, the dominant influence on signal level and coherence appeared to be the introduction of roughness on the bottom interface. Source motion relative to this roughness (i.e. displacement) appeared to cause significant signal degradation at higher frequencies. However, Doppler effects due to source motion did not seem to appreciably influence signal coherence. Furthermore, the influence of the bottom roughness was clearly affected by the presence, or lack of, a sound channel. Specifically, if a sound channel existed which limited the amount of bottom interactions, then the source

## THESIS ABSTRACTS

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motion (doppler or displacement) did not seem to significantly affect signal coherence. It is expected that similar conclusions would be obtained by introduction of a rough surface.

Given the conditions considered here, if the sound velocity profile generates significant bottom interactions, then the optimal frequency bandwidth appears to be the lowest possible, particularly at ranges beyond approximately 1 km. For weak bottom interacting profiles, higher frequencies that can increase data transfer rates would be optimal. The limitations of such higher frequencies would predominantly be in TL, but even this did not exhibit appreciable frequency dependence for ducted propagation.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Modeling and Simulation

**KEYWORDS:** Underwater Acoustic Communication, Bandwidth Optimization, Signal Coherence

### **ADVANCED APPLICATIONS FOR 0.53 $\mu\text{m}$ LASER LIGHT**

**W. David Jones-Captain, United States Army**

**B.S., North Carolina State University, 1990**

**Master of Science in Physics-June 2001**

**Advisors: William L. Kruer, Lawrence Livermore National Laboratory Chair Professor**

**William B. Colson, Department of Physics**

Use of the National Ignition Facility with green light as the laser output is an intriguing option for advanced applications ranging from inertial fusion to production of compact x-ray sources. Particular attention is given to the potential use of 0.53  $\mu\text{m}$  light to produce a high-energy x-ray source. This application requires the efficient generation of high-energy electrons which can subsequently produce high-energy x-rays as they transport into gold or other high Z wall. One- and two-dimensional computer simulations are used to explore high-energy electron generation by intense 0.53  $\mu\text{m}$  laser light in a plasma with density near one-quarter the critical density. Significant absorption is shown to occur into high-energy electrons with an effective temperature which is reduced by the development of ion fluctuations. The results compare favorably with some recent experiments using 0.53  $\mu\text{m}$  light.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Computing and Software

**KEYWORDS:** High Intensity Lasers, Laser-Plasma Coupling, National Ignition Facility, Fusion, Computer Simulations

### **RADIATION EFFECTS ON InGaAs p-i-n PHOTODIODES**

**James K. Kalowsky-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1991**

**Master of Science in Applied Physics-December 2000**

**Advisors: Todd R. Weatherford, Department of Electrical and Computer Engineering**

**James Luscombe, Department of Physics**

This thesis identifies, characterizes, and identifies a method to predict the dark current degradation of InGaAs p-i-n Photodiodes caused by exposure to 55 MeV protons, 12 MeV protons, and 90 MeV electrons. Experimental proton and electron fluence levels (particles/cm<sup>2</sup>) were calculated and correlated to fluence levels for a 1 MeV neutron in silicon by equating the amount of physical damage incurred within the device. Physical damage was quantified as a displacement damage dose ( $D_d$ ), which is simply the fluence level multiplied by the appropriate value for the material's non-ionizing energy loss (NIEL). Photodiodes were then irradiated and dark current data was collected. The resulting data were fitted into the three-term diode equation, and current coefficients were obtained. Proton data were used to document device performance, and to examine the relationship between fluence levels and changes in the current coefficients. Additionally, these data were used to verify that it is appropriate to use NIEL and  $D_d$  for the correlation of 55 MeV and 12 MeV protons. Electron data were also used to document device performance,

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## THESIS ABSTRACTS

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but failed to demonstrate the ability of NIEL and  $D_d$  to accurately match the predicted changes in device performance caused by 90 Mev electrons and 55 MeV protons.

**DoD KEY TECHNOLOGY AREA:** Electronics, Other (Radiation Effects)

**KEYWORDS:** Radiation, InGaAs Photodetectors

### **DESIGN AND DEVELOPMENT OF THE IMAGE SCANNER FOR LINEATE IMAGING NEAR ULTRAVIOLET SPECTROMETER (LINUS)**

**Ricardo C. Kompatzki-Lieutenant, Navy of Chile**

**B.S., Navy of Chile Polytechnic Academy, 1994**

**Master of Science in Applied Physics-December 2000**

**Advisors: D. Scott Davis, Department of Physics**

**Richard C. Olsen, Department of Physics**

The Lineate Imaging Near Ultraviolet Spectrometer (LINUS) is a spectral imager that works in the ultraviolet region of the spectrum, and its purpose is to study atmospheric gas plumes. This thesis project is part of an ongoing effort to field-test the first version of LINUS by mid-2001. It concentrates in the development of the ultra-precise servo system that controls the pointing/scanning system of the instrument. The closed-loop angular-position servo is controlled by a dedicated motion controller board that is installed in the host computer. Control of the servo is achieved through proportional-integral-derivative (PID) algorithms built into the hardware and firmware of the motion controller board. The servo has been designed to an angular resolution of 9 seconds of arc, and was tuned for a step of 1000 counts. Static and dynamic tests were conducted and showed that the servo is stable and accurate. The tested accuracy of the servo is well within the design goal of one half encoder count.

**DoD KEY TECHNOLOGY AREAS:** Chemical and Biological Defense, Environmental Quality, Sensors

**KEYWORDS:** Sensors, Spectral Imaging, Spectrometer, Remote Sensing

### **TIME DELAY ESTIMATION FOR UNDERWATER SIGNALS AND APPLICATION TO LOCALIZATION**

**Stefanos D. Kouteas-Lieutenant Junior Grade, Hellenic Navy**

**B.S., Hellenic Naval Academy, 1992**

**Master of Science in Engineering Acoustics-June 2001**

**Master of Science in Electrical Engineering-June 2001**

**Advisors: Charles W. Therrien, Department of Electrical and Computer Engineering**

**Kevin B. Smith, Department of Physics**

The problem of time difference of arrival (TDOA) is important in underwater acoustics for both passive and active sonar. Classical approaches to this problem are based on generalized cross-correlation (GCC) methods implemented in the frequency domain. After appropriate weighting of the cross spectral data in the frequency domain, an inverse discrete Fourier transform (IDFT) is performed and the peak of the resulting GCC function is located in the time domain.

This thesis shows that the cross-spectrum of the data satisfies an appropriate signal subspace model; therefore the IDFT can be replaced with a signal subspace technique such as MUSIC. The result is an enhanced ability to locate the peak. Further, application of methods such as root-MUSIC or ESPRIT produce direct numerical estimates for TDOA without the need to search for a peak. Results are presented for an extensive set of simulations using both synthetic signal data and data from a ocean acoustic propagation model (MMPE). Results are further presented for an application of the new method to target localization and tracking. In all cases results are compared using both the new methods and the classical methods.

## THESIS ABSTRACTS

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**DoD KEY TECHNOLOGY AREAS:** Other (Underwater Acoustics, Signal Processing)

**KEYWORDS:** Time Difference of Arrival, Subspace Methods, Generalized Cross-Correlation, Localization

### **MODELING TOTAL DOSE RADIATION EFFECTS IN A MULTI-EDGE SOI nMOSFET**

**Victor A. Lake-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1994**

**Master of Science in Physics-December 2000**

**Advisors: Todd Weatherford, Department of Electrical and Computer Engineering**

**James Luscombe, Department of Physics**

Silicon-On-Insulator (SOI) devices provide inherent radiation-hardness for dose-rate and single-event upset effects that makes them ideally suited for radiation environments such as space. Specifically, the SOI Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET), with its many Si/SiO<sub>2</sub> interfaces, is normally only sensitive to total dose radiation effects. This thesis investigates how to model these effects accurately and develops a computer simulation methodology utilizing hole trapping for modeling total dose radiation effects in a SOI semiconductor device. Specifically, a commercial Technology Computer Aided Design (TCAD) application, modified to include total dose radiation effects, is used to simulate an irradiated n-channel, multi-edge SOI MOSFET. The accuracy of the model is evaluated by using the simulation data to calculate simplified radiation induced leakage currents at various radiation dosages and then comparing with experimental measured leakage currents from irradiated devices. Simulation results show that while hole trapping is a dominant mechanism in causing enhanced leakage current at lower dose levels, it cannot solely account for all the enhanced leakage that occurs in a multi-edge device at higher dose levels.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Modeling and Simulation

**KEYWORDS:** Electronics, Silicon-on-Insulator (SOI), Modeling and Simulation, Radiation Hardened

### **SIMULATIONS OF THE TJNAF FEL WITH A TAPERED UNDULATOR AND EXPERIMENTAL RESULTS OF LASER DAMAGE**

**Dimitrios Lampiris-Lieutenant, Hellenic Navy**

**B.S., Hellenic Naval Academy, 1991**

**Master of Science in Applied Physics-December 2000**

**Advisor: William B. Colson, Department of Physics**

**Robert L. Armstead, Department of Physics**

The modern maritime battlefield is dominated by the new generation of sea-skimming, high-speed, stealthy and highly agile anti-ship missiles. Anti-ship cruise missile technology continues to evolve, overcoming the performance of the existing ship self-defense weapon systems. The Free Electron Laser (FEL) could be the ultimate speed-of-light hard kill weapon system, offering unique features such as tunability, high power, pinpoint accuracy and infinite magazine. Multimode computer simulations were used to explore the operation of the Thomas Jefferson National Acceleration Facility (TJNAF) FEL with untapered and positively tapered undulator. The final steady state power, the steady state gain and the electron energy spread as a function of desynchronization were determined for both 34.5 Mev and 47.5 Mev electron beam energies.

This thesis also includes an experimental study of damage induced to Polyimide Fiberglass and F2 Epoxy samples, by the TJNAF FEL. Irradiations of the samples were conducted changing various parameters, such as the wavelength, average power, pulse repetition frequency, cross wind and spot size in order to explore the damage mechanism. At this stage of evolution, TJNAF FEL is capable of 500 W output average power, and in order to achieve the required intensity of 10 kW/cm<sup>2</sup> the beam was focused to a small radius. Scaling guidelines were developed in order to predict the damage caused by a high power laser over a large area.

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## THESIS ABSTRACTS

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**DoD KEY TECHNOLOGY AREAS:** Directed Energy Weapons, Modeling and Simulation

**KEYWORDS:** Free Electron Laser, Ship Self-Defense, Tapered Undulator, Laser Damage Experiments

### **SIMULATION OF DARMSTADT FREE ELECTRON LASER AND A COMPARISON OF HIGH GAIN FREE ELECTRON LASERS**

**Daniel S. Massey-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1994**

**Master of Science in Physics-December 2000**

**Advisor: William B. Colson, Department of Physics**

**Second Reader: Robert L. Armstead, Department of Physics**

The Free Electron Laser, with its wavelength tunability unlike any other laser, may be used in numerous future applications. These applications range from high energy laser weapons to surgical lasers for medical use. This thesis covers three separate topics concerning the FEL: the height of the separatrix for a tapered undulator, use of dimensionless parameters in a simple model and description for several high gain free electron lasers, and simulations of the Darmstadt free electron laser. The first topic yielded a formula for the separatrix height. The second topic utilized data from the proposed LCLS and TESLA x-ray lasers, the Electron Laser Facility at Lawrence Livermore Labs and the Free Electron Laser experiments at the Massachusetts Institute of Technology to develop dimensionless parameters for use in a simple model. For the last topic desynchronization curves for seven tapers were computed and gave expected results.

**DoD KEY TECHNOLOGY AREAS:** Directed Energy Weapons, Modeling and Simulation

**KEYWORDS:** Free Electron Laser

### **FREE ELECTRON LASER DEVELOPMENT FOR DIRECTED ENERGY**

**Roger D. McGinnis-Commander, United States Navy**

**B.S., Georgia Institute of Technology, 1982**

**M.S., Naval Postgraduate School, 1994**

**Doctor of Philosophy in Physics-December 2000**

**Dissertation Supervisor: William B. Colson, Department of Physics**

This dissertation investigates power requirements for a Free Electron Laser to burn through various missile radome materials. It also includes computer simulation results for several FEL system configurations designed to achieve maximum power while maintaining strict energy spread constraints.

The method used to determine power requirements to burn through materials was to use the Thomas Jefferson National Accelerator Facility's Free Electron Laser to conduct material damage experiments. As the laser was improved and increased in power, the laser spot sizes on the target materials were increased while maintaining a constant irradiance. The key results from these experiments included determining minimal spot sizes that can be used for future experiments, and validation that an irradiance level of 10 kW/cm<sup>2</sup> can burn through most missile radome materials in a few seconds.

The computer simulations involved changing various parameters of an FEL such as electron energy levels, pulse lengths, magnetic field strengths, desynchronization, as well as several other parameters, to determine the best possible configuration to achieve the desire power levels and energy spread requirements for development of a megawatt size FEL. The results indicate that for the proposed designs, both the required power and the required energy spread limit can be met.

**DoD KEY TECHNOLOGY AREAS:** Directed Energy Weapons, Materials, Processes and Structures, Modeling and Simulation

**KEYWORDS:** Free Electron Laser, Laser Damage, Anti-Ship Cruise Missiles

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## THESIS ABSTRACTS

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### **EFFECTIVENESS OF MODELING A HIGH POWER RADIO FREQUENCY (HPRF) WEAPON SYSTEM (U)**

**Stephen R. Meade-Lieutenant, United States Navy**  
**B.S., North Carolina State University, 1993**  
**Master of Science in Applied Physics-December 2000**  
**Master of Science in Physics-December 2000**

**and**

**Robert S. Thompson-Lieutenant, United States Navy**  
**B.S., United States Naval Academy, 1993**  
**Master of Science in Applied Physics-December 2000**  
**Master of Science in Physics-December 2000**

**Advisors: Michael A. Morgan, Department of Electrical and Computer Engineering**  
**Donald Walters, Department of Physics**

**CAPT James R. Powell, USN, Information Warfare Academic Group**

The objective of this research was to model the electromagnetic output of a proposed High Power Radio Frequency (HPRF) weapon system. The antenna data was generated using GNEC, a method of moments computational electromagnetic code. The impulsive excitation and resultant transient near-fields were modeled using electrical circuit analysis and inverse Fast Fourier Transformation programmed in MATLAB 5.3. The peak amplitudes and waveforms were the primary focus of this study.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Directed Energy Weapons, Modeling and Simulation

**KEYWORDS:** Electronic Warfare, Directed Energy Weapons, Antenna Design, Antenna Modeling, Electromagnetic Simulation

### **CONSTRUCTION AND TESTING OF A MODERN ACOUSTIC IMPEDANCE TUBE**

**Sean P. O'Malley-Lieutenant Commander, United States Navy**  
**B.S., United States Naval Academy, 1989**

**Master of Science in Applied Physics-June 2001**

**Advisor: Steven R. Baker, Department of Physics**

**Second Reader: Thomas J. Hofler, Department of Physics**

The acoustic impedance of a material describes its reflective and absorptive properties. Acoustic impedance may be measured in a wide variety of ways. This thesis describes the construction and testing of an acoustic impedance measurement tube which employs modern Fourier Transform techniques. Two methods are employed for acoustic impedance measurement using this apparatus. One technique uses a two-microphone continuous excitation method and the other uses a single microphone transient excitation method. Simple acoustic theory is used to derive equations for both methods. MATLAB computer programs are developed using these equations, to provide graphical results of acoustic impedance measurements over a frequency range for a given material, from raw data. A procedure is subsequently developed for using this apparatus to make acoustic impedance measurements. The performance of this device is evaluated by making measurements utilizing both methods on three sample materials and also with the end of the tube open to the atmosphere (referred to as an open tube measurement). The open tube measurements are compared with theoretical values. The results using both approaches compared favorably with the open tube theoretical values. Additionally both approaches agreed reasonably well with each other for the three sample materials. Performance at frequencies below 500 Hz, however, yielded deficient results, indicating a need for development of a filter for better accuracy.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Acoustic Impedance Measurement, Acoustic Impedance Tube, Reflection

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## THESIS ABSTRACTS

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### **ENERGETIC ELECTRON GENERATION BY FORWARD STIMULATED RAMAN SCATTERING USING 0.35 AND 0.53 MICRON LASER LIGHT IN A PLASMA**

**Michael A. Ortelli-Major, United States Army**

**B.S., United States Military Academy, 1990**

**Master of Science in Applied Physics, June 2001**

**Advisor: William L. Kruer, Lawrence Livermore National Laboratory Chair Professor**

**Second Reader: William B. Colson, Department of Physics**

This research investigates the use of high-powered lasers to produce 50-100 keV x-ray sources for applications for programs such as Stockpile Stewardship and nuclear weapons effects testing (NWET). To produce these x-ray sources requires irradiating targets with intense laser light to efficiently generate high-energy electrons. Stimulated Raman scattering (SRS) of intense laser light produces electron plasma waves, which in turn generate high-energy electrons. To make a high-energy x-ray source, the maximization of this laser-driven instability is desired. Using computer simulations, we show that forward SRS can grow by using a combination of frequency-tripled and a "seed" beam of frequency doubled laser light in a plasma of the appropriate density. Electron plasma waves with a high phase velocity are produced, which trap electrons and accelerate them to high energy. These energetic electrons will in turn generate high energy x-rays via collisions with nearby dense material. By adjusting the angle between the 0.35  $\mu\text{m}$  and 0.53  $\mu\text{m}$  laser beams, the characteristic temperature of the heated electrons (and the x-rays) can be varied. We show one and two-dimensional simulations and illustrate the important role that laser-driven ion fluctuations play.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (Stockpile Stewardship Program, Nuclear Weapons Effect Testing)

**KEYWORDS:** Laser-Plasma Interactions, Stimulated Raman Scattering, Plasma Instabilities

### **SIMULATION OF AN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING BASED UNDERWATER COMMUNICATION SYSTEM USING A PHYSICS BASED MODEL FOR THE UNDERWATER ACOUSTIC SOUND CHANNEL**

**Gell Tiger Lee Pittman, III-Lieutenant, United States Navy**

**B.S., South Dakota School of Mines and Technology, 1994**

**Master of Science in Engineering Science-September 2001**

**Advisors: Roberto Cristi, Department of Electrical and Computer Engineering**

**Kevin B. Smith, Department of Physics**

The primary thrust of this thesis is the development of a computer-based simulation of an Orthogonal Frequency Division Multiplexing (OFDM) based underwater acoustic communication system. The product will support the testing and evaluation of various digital signal processing algorithms applicable to underwater acoustic communication systems using OFDM as well as the study of the effects of the acoustic channel and communication system factors on the key parameters of the system such as bit error rate, received signal to noise ratio, frequency band of employment and overall system bit rate. The underwater acoustic sound channel is modeled using a physics based parabolic equation approximation. The simulation models the key components in the transmitter and receiver that contribute to the overall performance of the system. The results of the thesis provide expected values for system performance in terms of bit rate, bit error rate and received SNR for given frequency bands and are validated through comparison to theoretically derived expectations and to ocean testing of OFDM underwater communication systems.

**DoD KEYTECHNOLOGY AREAS:** Other (Underwater Acoustics)

**KEYWORDS:** Orthogonal Frequency Division Multiplexing, OFDM, Underwater Acoustic Sound Channel

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## THESIS ABSTRACTS

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### **TERRAIN CATEGORIZATION USING MULTITEMPORAL SYNTHETIC APERTURE RADAR (SAR)**

**James G. Reese, Jr.-Lieutenant, United States Navy  
B.S., Pennsylvania State University, 1995**

**Master of Science in Systems Technology-June 2001**

**Advisors: Richard C. Olsen, Department of Physics**

**Alan A. Ross, Navy Tactical Exploitation of National Capabilities (TENCAP) Chair Professor**

Multitemporal synthetic aperture radar (SAR) imagery is exploited for the purpose of Terrain Categorization (TERCAT). This thesis explores using SAR data from National Technical Means (NTM) to construct detailed TERCAT maps. Two littoral military locations were imaged multiple times over a three-month period. These images were registered to each other and combined to form multi-band composite images. Unsupervised and supervised classification techniques were then used to construct TERCAT maps of the two littoral military locations. The unsupervised and supervised classification techniques used unique spectral elements in the multi-band composite images to assign each pixel in the composite images to a terrain class. The TERCAT maps were compared with ground truth measurements to determine the overall categorization accuracy with good results. The military utility of the TERCAT techniques and products was explored with an emphasis on the intelligence value.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Remote Sensing, Sensor Fusion, TERCAT

### **TARGETING AND FIRE CONTROL SYSTEM ANALYSIS OF THE NEW TURKISH ATTACK HELICOPTER "THE AH-1Z KINGCOBRA"**

**Gokhan Lutfu Reyhan-First Lieutenant, Turkish Army**

**Master of Science in Aeronautical Engineering-March 2001**

**Advisors: Russ Duren, Department of Aeronautics and Astronautics**

**Alfred W. Cooper, Department of Physics**

In May of 1997, the Turkish Military issued a Request for Proposal for the purchase of 145 attack helicopters. Turkey has chosen Bell Helicopter's KingCobra as its attack helicopter. The major difference between the USMC version of AH-1Z and the Turkish version KingCobra is the Targeting and Fire Control System. Bell Helicopter Textron has chosen Lockheed Martin to develop and build a new targeting system, the Target Sight System (TSS). The TSS will contain Lockheed Martin's 3-5 $\mu$ m midwave staring array FLIR. On the other hand, the Turkish Secretariat for Defense Industries (SSM) has chosen Aselsan ASELFLIR-300T that contains an 8-12 $\mu$ m longwave scanning second-generation FLIR.

A comparison of range performance for these two systems has been made using the TAWS Field Performance Model. Since the physical parameters on these specific FLIRs are proprietary, the FLIR92 Simulation Mode is used to generate performance parameters. These parameters are expected to represent the general characteristics of the two systems. The resultant data is used in the TAWS Field Performance Model to predict the range performances.

The results have showed that the staring array midwave FLIR has longer ranges in the scenarios given in this thesis. This may not represent the real performance of the systems.

**DoD KEY TECHNOLOGY AREAS:** Air Vehicles, Sensors, Other (Thermal Imaging Systems)

**KEYWORDS:** Thermal Imaging Systems, Targeting, Fire Control Systems, Forward Looking Infrared, FLIR, TAWS, KingCobra, Attack Helicopter, Infrared



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## THESIS ABSTRACTS

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### **EXPERIMENTAL USE OF THE LAWRENCE LIVERMORE DEVELOPED MICRO-POWER SHORT PULSE RADAR TO EXTRACT LOW AMPLITUDE MODULATION SIGNALS CORRESPONDING TO HUMAN HEART RATES**

**Steven M. Rutherford-Lieutenant Commander, United States Navy  
B.S., United States Naval Academy, 1990**

**Master of Science in Applied Physics-September 2001**

**Advisor: Capt J. Scott Tyo, USAF, Department of Electrical and Computer Engineering  
Second Reader: Richard M. Harkins, Department of Physics**

Detecting a living person buried in rubble or concealed in buildings has far reaching search and rescue as well as military applications. This thesis developed a filter from a catalog of close range impulse response signals that were acquired using Micro-power Short Pulse Radar developed at Lawrence Livermore National Laboratory.

Utilizing matched filtering techniques, low amplitude modulations signals corresponding to the human heart were extracted from return signals out to 40 feet. Human heart signals were extracted from return signals in air and through different materials. The matched filter output of the signal compared with the noise was then used to develop detection probabilities and performance characteristics based on range and material.

**DoD KEY TECHNOLOGY AREA:** Human-Systems Interface

**KEYWORDS:** Human Heart Signals, Human Heart Rates, Micro-Power Short Pulse Radar

### **EXPLOITATION OF NATIONAL SENSORS FOR TERRAIN CATEGORIZATION (U)**

**Charles S. Seitz-Lieutenant Commander, United States Navy  
B.S., United States Naval Academy, 1982**

**Master of Science in Astronautical Engineering-March 2001**

**Advisors: Richard C. Olsen, Department of Physics  
Brij N. Agrawal, Department of Aeronautics and Astronautics**

Abstract is classified.

**DoD KEY TECHNOLOGY AREAS:** Space Vehicles, Sensors, Other (Intelligence, Indications and Warning (I&W))

**KEYWORDS:** Sensor Fusion, Multispectral Imaging, Imagery Intelligence, TERCAT

### **DETONABILITY OF HYDROCARBON/AIR MIXTURES USING COMBUSTION ENHANCING GEOMETRIES FOR PULSE DETONATION ENGINES**

**Neil G. Sexton-Lieutenant, United States Navy  
B.S., United States Naval Academy, 1995**

**Master of Science in Applied Physics-June 2001**

**Advisors: Christopher M. Brophy, Department of Aeronautics and Astronautics  
James V. Sanders, Department of Physics  
Second Reader: David W. Netzer, Department of Aeronautics and Astronautics**

This research studied combustion enhancing geometries and shock reflection on generating a hydrocarbon/air detonation wave in a combustion tube. Ethylene was used as a baseline fuel to determine the preferable geometries. Propane was then used in later testing because of its combustion similarities with heavy hydrocarbon fuels such JP5, JP8, and JP10. Three criteria were used to measure the effectiveness of the combustion enhancing geometries: ability to generate a detonation, wave speed, and time for shock formation. The evaluated geometries included flow-restricting orifice plates and a Schelkin spiral. The shock reflection was accomplished by a vertical fence (large orifice) placed in the last fourth of the tube length. The optimum geometry was found to be the orifice plate used in conjunction with the

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spiral. Detonations occurred when using ethylene in this configuration, but did not develop when using propane. Because propane's overall reaction rate is slower than that of simpler fuels, more large- and small-scale turbulence to further enhance combustion needs to be generated to create a detonation wave in a short distance when using complex hydrocarbons, such as propane.

**DoD KEY TECHNOLOGY AREA:** Aerospace Propulsion and Power

**KEYWORDS:** Detonation, Pulse Detonation Engine, Deflagration to Detonation Transition, DDT

### **ADVANCEMENTS IN BURIED MINE DETECTION USING SEISMIC SONAR**

**Kraig E. Sheetz-Captain, United States Army**

**B.S., Millersville University, 1990**

**M.S., New Mexico Tech, 1992**

**Master of Science in Applied Physics-December 2000**

**Advisor: Thomas G. Muir, University of Texas-Austin**

**Second Reader: Steven R. Baker, Department of Physics**

Buried mines continue to disrupt the U.S. ability to project naval power ashore, conduct amphibious assaults, and wage land campaigns. This thesis describes advances in the development of a seismic sonar research tool that resulted in the successful detection of a Mk-63, 1000 lb, mine shape and a M-19, 20 lb, anti-tank mine. This seismic sonar research investigates the concept of using echo returns of a particular seismic interface wave, known as a Rayleigh wave, to detect buried mines. Rayleigh waves are unique in that they have elliptical particle motion that allows one to use vector polarization filtering to separate Rayleigh wave target reflections from other body waves with linear particle motion. A new source design employed in an array of seven elements has been shown to form a narrow beam of Rayleigh wave energy in a sand medium at the navy beach test site. This source beam, coupled with the receiver beam formed by an array of five three-component seismometers has provided a successful bi-static seismic sonar configuration. Signal to noise ratios of 21 dB for the Mk-63 mine shape, and 9 dB for the M-19 anti-tank mine were observed in the target echoes. These experimental results suggest that the seismic sonar is a very promising concept for buried mine detection.

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Sensors

**KEYWORDS:** Mine Warfare, Buried Mine Detection, Seismic Sonar, Surface Waves

### **PSPICE MODELING AND PARAMETRIC STUDY OF MICROBOLOMETER THERMAL DETECTORS**

**Scott W. Stetson-Lieutenant, United States Navy**

**B.A., Duke University, 1994**

**Master of Science in Applied Physics-June 2001**

**Advisors: Gamani Karunasiri, Department of Physics**

**D. Scott Davis, Department of Physics**

The operation of a bolometer thermal sensor is analogous to that of a charging capacitor in a generic RC circuit. As such, circuits containing bolometers can be analyzed with standard circuit simulation programs such as PSPICE. This thesis deals with the development of a bolometer model by using PSPICE with the aid of Analogue Behavior Modeling (ABM) capability, which allows the user to program circuit components with basic mathematical functions. The predictions of the model were found to be in good agreement with the reported data of an experiment previously conducted, which demonstrates the accuracy of the model. The model was used to design a self-heating compensated thermal sensor with enhanced signal integration capability to improve the signal-to-noise ratio. We believe the model can be used to analyze any circuit containing bolometers to optimize the performance.

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## THESIS ABSTRACTS

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**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Microbolometer, Bolometer, Thermal, Sensor, PSPICE, Computer Modeling, Thermal Imaging

### EXPERIMENTAL STUDIES OF TWO-WAY SINGLE ELEMENT TIME-REVERSAL IN A NOISY WAVEGUIDE

John P. Stokely-Lieutenant Commander, United States Navy

B.S., University of Connecticut, 1988

Master of Science in Applied Physics-June 2001

Advisors: Andrés Larraza, Department of Physics

Mitchell N. Shipley, Pennsylvania State University

As the United States Navy considers operation closer to shore, it must account for the impact of shallow water ocean environments on the performance of active sonar. Multi-path propagation and high ambient noise in these areas pose a unique detection challenge for current sonar systems. A possible solution for this problem involves the use of processing that is actually enhanced by multi-path propagation, and can perform in the presence of in-band noise. Time-Reverse Acoustics (TRA) has been used with many transducer elements to focus acoustic energy in a very small region. Used as a single element active sonar, it can focus the return of an active pulse at the receiver location.

To test the performance of a TRA-based sonar in the presence of noise, ultrasonic signals were used in a laboratory waveguide, so that the scale of wavelength to water depth approximates a shallow channel with a flat, lossy bottom. Several sequences of a traditional sinusoidal pulse and the time-reversed reception were performed with varying noise levels. The gain in detection signal-to-noise ratio (SNR) was on average 7.3+0.8dB using TRA. Further, the TRA processing provided a noticeable detection when noise had completely obscured the reception of the initial pulse.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Time Reverse Acoustics, Active Sonar, Signal-to-Noise Ratio (SNR), Waveguide

### APPLICATIONS OF LARGE AMPLITUDE BROADBAND ACOUSTIC NOISE TO ACOUSTOPHORESIS

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B.S., United States Naval Academy, 1981

M.S., Johns Hopkins University, 1988

Doctor of Philosophy in Physics-September 2001

Dissertation Supervisor: Andres Larraza, Department of Physics

Theoretical results show that the drag on a resonant object can be modified by the presence of homogeneous, broadband acoustic noise, when the band overlaps the object's resonance width. While the results constitute an acoustic analog to the Einstein-Hopf drag on an oscillating dipole in the presence of electromagnetic fluctuations, an important difference is that band limited acoustic noise can reduce the drag when the lower frequency of the spectrum coincides with the resonant frequency of the resonator. Experimental evidence of the increased drag on a bubble is shown. Both increased and reduced drag on aerogel spheres configured as the bob of a parametrically driven pendulum are reported. Applications to separation processes, in particular a design that can be used for extraction of water in both fuel and lubrication oil systems and extraction of oil in bilge water, are suggested.

**DoD KEY TECHNOLOGY AREAS:** Other (Acoustics)

**KEYWORDS:** Acoustic Noise, Acoustophoresis

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## THESIS ABSTRACTS

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### FEASIBILITY OF PARAMETRIC EXCITATION OF ACOUSTIC RESONATORS

Larry P. Varnadore-Lieutenant, United States Navy

B.S., Auburn University, 1993

Master of Science in Applied Physics-June 2001

Advisor: Bruce Denardo, Department of Physics

Second Reader: Thomas J. Hofler, Department of Physics

This thesis examines the feasibility of parametrically exciting a mode of an acoustic resonator. Such excitation may result in substantially larger amplitudes than by direct excitation, and would thus be useful in acoustic devices that require high-amplitude standing waves. Parametric excitation of a mode occurs if the natural frequency is modulated at twice its value, and if the drive amplitude is above a threshold value due to dissipation. It is theoretically shown to be possible to excite the fundamental longitudinal mode of a pipe of any length filled with sulfur hexafluoride if the length is modulated with an Electrovoice EVX-150A driver. For carbon dioxide, excitation is predicted to occur if the pipe is longer than 1.2 meters. Also investigated is parametric excitation of the fundamental radial mode of a cylindrical cavity by modulating the height and thus the temperature. In this case, no driver was found to be capable of exceeding the threshold, regardless of the gas. Use of an electromagnetic wave source to modulate the temperature was also considered as a means of parametrically exciting the fundamental radial mode. Preliminary investigations show that sufficient heat conduction cannot occur over an acoustic cycle, indicating that this method is infeasible.

**DoD KEY TECHNOLOGY AREA:** Other (Acoustics)

**KEYWORDS:** Parametric Excitation, Acoustic Resonator, Acoustics

### MODELING SECOND GENERATION FLIR SENSOR DETECTION RECOGNITION AND IDENTIFICATION RANGE WITH POLARIZATION FILTERING

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Master of Science in Applied Physics-December 2000

Advisors: Alfred W. Cooper, Department of Physics

Ron Pieper, Department of Electrical and Computer Engineering

The influence of polarization filtering on maximum detection, recognition, and identification ranges of a generic second generation FLIR sensor is examined with a computational model. The scenario studied represents a second generation FLIR sensor mounted on an aircraft in level flight at 300m approaching a ship target. The target ship radiant signature is modeled with an advanced infrared signature prediction program, MuSES (Multi-Service Electro-Optic Signature). A weather file representative of Midlatitude Summer at sea conditions was utilized. Polarized sea background and path radiance calculations are performed with a polarized version of the SEARAD Radiance and Propagation Code. Results showed that there is an improvement in maximum range of the sensor for detection, recognition, and identification tasks when a horizontal filter is included, provided that the target does not have a negative degree of polarization. For detection task the improvements were found to be 33.48%, 35.65%, and 39.78% when the target has 0%, +2%, and +8% degree of polarization respectively. A better modeling of Apparent Temperature Difference (ATD) calculation is also developed. To improve the model use of polarized target model is recommended.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Modeling and Simulation

**KEYWORDS:** Thermal Imaging Systems, Minimum Resolved Temperature Difference, Polarization Filters

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## THESIS ABSTRACTS

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### **APPLICATION OF THE ROBUST SYMMETRICAL NUMBER SYSTEM TO HIGH RESOLUTION DIRECTION FINDING INTERFEROMETRY**

**Nathan S. York-Lieutenant, United States Navy  
B.S., Worcester Polytechnic Institute, 1994**

**Master of Science in Applied Physics-December 2000**

**Advisors: Phillip E. Pace, Department of Electrical and Computer Engineering  
D. Scott Davis, Department of Physics**

This research has examined the benefits of using the Robust Symmetrical Number System (RSNS) to resolve ambiguities in phase sampling interferometry. A compact, high resolution direction finding antenna architecture based on the RSNS was developed to demonstrate experimentally the elimination of phase errors using a minimum amount of hardware. Previous work has determined that phase errors in the system will degrade the system performance. Several improvements were made to the original RSNS prototype antenna to provide enhanced performance. Adding isolators and supplementing the ground plane with copper tape (between the antenna elements), a reduction in the mutual coupling effects was accomplished. Mounting the microwave components on a brass plate also reduced errors contributed by vibrations and temperature. Tailor cutting all semi-rigid coaxial lines also helped reduce the number of connectors required to assemble the microwave circuit, also a source of phase errors. Matching the front-end amplifiers in each amplification stage rather than matching the characteristics of two cascaded amplifiers in each signal line has reduced relative phase errors between channels as well as matching the power outputs of the amplifiers. Two printed circuit boards were designed and built for the RSNS signal processor. The printed circuit boards provide a decrease in the electrical noise floor over the original design (assembled on breadboards). The new design has reduced the phase errors that were present in the first prototype system. The RSNS signal processing technique is able to provide a high-resolution phase sampled direction finding capability with an angular resolution of 1.9 degrees by using only three receiving elements (two interferometers).

**DoD KEY TECHNOLOGY AREAS:** Sensors, Electronic Warfare

**KEYWORDS:** Robust Symmetrical Number Systems, Optimum Symmetrical Number Systems, Phase Sampling Interferometry, Direction Finding, Ambiguity Resolution

### **NETWORK DEFENSE-IN-DEPTH: EVALUATING HOST-BASED INTRUSION DETECTION SYSTEMS**

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**Master of Science in Systems Technology-June 2001  
and**

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As networks grow, their vulnerability to attack increases. DoD networks represent a rich target for a variety of attackers. The number and sophistication of attacks continue to increase as more vulnerabilities and the tools to exploit them become available over the Internet. The challenge for system administrators is to secure systems against penetration and exploitation while maintaining connectivity and monitoring and reporting intrusion attempts.

Traditional intrusion detection (ID) systems can take either a network or a host-based approach to preventing attacks. Many networks employ network-based ID systems. A more secure network will employ both techniques. This thesis will analyze the benefits of installing host-based ID systems, especially on the critical servers (mail, web, DNS) that lie outside the protection of the network ID system/Firewall. These servers require a layer of protection to ensure the security of the entire network and reduce the risk or attack.

## THESIS ABSTRACTS

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Three host-based ID systems will be tested and evaluated to demonstrate their benefits on Windows 2000 Server. The proposed added security of host-based ID systems will establish defense-in-depth and work in conjunction with the network-based ID system to provide a complete security umbrella for the entire network.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Network Security, System Security, Intrusion Detection, Intrusion Detection System, Defense-in-depth

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