
PROJECT SUMMARIES

NUMERICAL MODELING OF SONAR TRANSDUCERS AND ARRAYS

Steven R. Baker, Associate Professor
Department of Physics
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Department of Mathematics
Sponsor: Office Naval Research

OBJECTIVE: Support is sought for three tasks: (1) to conduct a survey of available numerical structural/acoustic computer codes, (2) to tabulate the capabilities of each in the key areas pertinent to sonar transducers and array modeling, and (3) to continue development of the T-matrix method for the performance modeling of arbitrarily densely- and randomly-packed sonar arrays. Specifically, it is proposed to continue to investigate codes to computer acoustic scattering, with particular attention to the nearfield, and host a sonar transducer and array modeling workshop at the Naval Postgraduate School.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Active Sonar, Transducer, Array, Modeling, Finite-Element

ANALYSIS OF VIBRATION MEASUREMENTS IN SUPPORT OF THE ELECTRO-OPTICAL SENSOR UPGRADE TO THE PHALANX CLOSE-IN WEAPON SYSTEM

Steven R. Baker, Associate Professor
Department of Physics
Sponsor: Naval Surface Warfare Center-Dahlgren Division

OBJECTIVE: To continue analysis of vibration measurements made in FY96 on a prototype of the new Phalanx electro-optical sensor package during a live-fire exercise. In particular, to analyze the rotation of the FLIR camera mount and the plane of the stabilizer pedestal feet.

DoD KEY TECHNOLOGY AREA: Conventional Weapons

KEYWORDS: Phalanx CIWS, Structural Vibration, Vibration

AN INVESTIGATION OF THE USE OF POLARIZATION WITH THE HYDICE HYPERSPECTRAL IMAGER

David D. Cleary, Associate Professor
Department of Physics
**Sponsor: Navy Tactical Exploitation of National Capabilities Office and
Naval Postgraduate School**

OBJECTIVE: The objective of this project was to investigate the use of multispectral and hyperspectral polarization for automatic target recognition in satellite imaging systems. This is a new concept whereby the Stokes polarization parameters would be measured for every band of a multispectral imager or for every channel of a hyperspectral imager. Measurement of these parameters could greatly improve our automatic target recognition capabilities in support of military operations. While this technique adds a fourth dimension to the traditional 3-D data cube, it could actually lower the bandwidth requirements of existing and future imaging systems.

SUMMARY: Unlike "traditional" polarimetry, which typically involves panchromatic measurements of the angular dependent BRDF, focus was on the spectral dependence of polarization. The polarization signature was measured of 15 different materials of military interest. In general, hyperspectral polarization signature is positive and anti-correlated with reflectance. Degree-of-polarization increases with increasing angle-of-reflectance. Dark targets exhibit a larger degree-of-

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polarization than reflectance. Specular targets exhibit negative polarization. Distinctive polarization features are apparent for unpainted aluminum and synthetic fiber targets.

THESIS DIRECTED:

Rigo, M., "The Use of Polarization with Hyperspectral Imaging," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Hyperspectral Imaging

ULTRAVIOLET HYPERSPECTRAL IMAGING

David D. Cleary, Associate Professor

Department of Physics

Sponsor: United States Air Force

OBJECTIVE: The objective of this project is to measure the ultraviolet spectra of a variety of materials and gases of military interest to determine the existence of any significant spectroscopic signature. The overall goal is to assess whether there is added value in extending the spectral coverage of hyperspectral imagers to include the near ultraviolet (300 to 400 nm).

SUMMARY: To date, the UV spectra of over 15 materials commonly included in hyperspectral measurement studies have been measured. Based on these measurements, it is concluded that the UV signatures of these materials are not sufficiently unique to warrant a significant push toward shorter wavelengths. The use of ultraviolet remote sensing for the detection of gases, however, does show great promise. Sulfur dioxide has been chosen as an initial demonstration of this technique. SO₂ concentrations have been measured as low as 10 ppm-m and as high as 1500 ppm-m. Preparations are currently being made to make field measurements of the Pu'u O'o volcano in Hawaii.

THESIS DIRECTED:

Hooks, T.A., "Development and Testing of the NPS Ultraviolet Imaging Spectrograph (NUVIS)," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Hyperspectral Imaging

A NOVEL TECHNIQUE FOR SEARCH AND GEOLOCATION OF SIGNALS FROM LOW-EARTH ORBIT

David D. Cleary, Associate Professor

Department of Physics

Sponsor: United States Navy

OBJECTIVE: The objective is to investigate new techniques for search and geolocation using receiver systems that have both wide field-of-view and high gain.

SUMMARY: An imaging system was designed that can operate at radar frequencies and has in principle both wide field-of-view and high gain. This system makes use of a technique known as multiplexed imaging. The concept of operations

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(CONOPS) under which this device would be used was developed. Currently, the expected performance of this device is being analyzed including the estimated sources of system noise.

OTHER:

A Multiplexed Imaging System for Microwave Frequencies, Navy Case No. 78779 (patent filed).

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Hyperspectral Imaging

FREE ELECTRON LASER FOR SHIP DEFENSE

William B. Colson, Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: The research is proposed for the study of the high-average-power infrared wavelength free electron laser developed by the Navy's Directed Energy Office at the Jefferson National Laboratory (formerly CEBAF), Newport News, VA.

SUMMARY: The Navy's Directed Energy Office is developing a high-power UV free electron laser for industrial processing. NPS has used numerical simulations to help guide the design and development. The design also meets many of the requirements for a high-power shipboard laser weapon. The Navy's Directed Energy Office's proposed design is powered by a super-conducting RF accelerator that would produce 100 kW of laser power at UV wavelengths and would cost about \$30 M.

PUBLICATIONS:

Colson, W.B., "Short Wavelength Free Electron Lasers in 1996," *Nuclear Instruments and Methods in Physics Research A393*, 6, 1997.

Colson, W.B., "Theory of High Gain Free Electron Lasers," *Nuclear Instruments and Methods in Physics Research A393*, 82, 1997.

CONFERENCE PRESENTATION:

Colson, W.B., "The World's First X-Ray Laser," Physics Department Colloquium, Naval Postgraduate School, Monterey, CA, July 1997.

THESIS DIRECTED:

Small, D.W., "Interaction of Laser Beams With Relativistic Electrons," Doctor of Philosophy Dissertation, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Manufacturing Science and Technology

KEYWORDS: Free Electron Laser, Industrial Laser Processing

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NORTHROP/GRUMMAN FREE ELECTRON LASER RESEARCH

William B. Colson, Professor

Department of Physics

**Sponsor: Northrop/Grumman Advanced Technology and
Development Center, Bethpage, NY**

OBJECTIVE: Northrop/Grumman is interested in developing the free electron laser technology for industrial and military applications requiring high average power.

SUMMARY: Northrop/Grumman has developed a low power free electron laser (FEL) for scientific use in the far infrared wavelength range. They are developing the accelerator and FEL technology that applies to high average power capable of defending Navy ships against sea-skimming cruise missiles. Simulations describe the performance of an FEL capable of damaging cruise missiles at a range of about 10 km. The power requirements that must be provided by the ship are studied. NPS and Northrop/Grumman have collaborated on the requirements for shipboard deployment of a 1 MW FEL. Research studied the packaging of the Northrop/Grumman FEL technology for Navy ship defense and to compare Northrop/Grumman and NPS FEL simulations.

PUBLICATION:

Todd, A.M.M., Colson, W.B., and Neil, G.R., "Megawatt-Class Free Electron Laser Concept for Shipboard Self-Defense," *SPIE* A2988, 176, 1997.

CONFERENCE PRESENTATION:

Todd, A.M.M., Colson, W.B., and Neil, G.R., "Megawatt-Class Free Electron Laser Concept for Shipboard Self-Defense," *SPIE LASER '97*, San Jose, CA, February 1997.

THESIS DIRECTED:

Restivo, R.A., "Free Electron Laser Weapons and Electron Beam Transport," Master's Thesis, Naval Postgraduate School, June 1997.

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

KEYWORDS: Free Electron Laser, High Energy Laser

HIGH POWER INFRARED FREE ELECTRON LASERS FOR SHIP DEFENSE

William B. Colson, Professor

Department of Physics

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The research studies high average power infrared wavelength free electron lasers (FELs) at the Thomas Jefferson National Accelerator Facility (formerly the Continuous Electron Beam Accelerator Facility), Newport News, VA. SPAWAR is developing the technology for using FELs to defend ships against sea-skimming missiles.

SUMMARY: NPS is working with the Jefferson National Laboratory (formerly CEBAF) and SPAWAR to develop the superconducting accelerator technology to power a 1 MW FEL for ship defense. The design must meet the requirements for a high-power shipboard laser weapon.

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PUBLICATIONS:

Anderson, E. and Colson, W.B., "Ship Design Optimization for a CEBAF Free Electron Laser," *Nuclear Instruments and Methods in Physics Research*, A393, II-149, 1997.

Small, D.W., Wong, R.K., Colson, W.B., and Armstead, R.L., "Free Electron Lasers with Short Rayleigh Length," *Nuclear Instruments and Methods in Physics Research*, A393, 262, 1997.

CONFERENCE PRESENTATIONS:

Kesselring, M., Colson, W.B., Wong, R.K., and Sheffield, R., "Simulations of the LANL Regenerative Amplifier FEL," poster paper at the Nineteenth International Free Electron Laser Conference, Beijing, China, August 1997.

Nguyen, R.T., Colson, W.B., Wong, R.K., and Sheffield, R., "Simulation of a Regenerative MW FEL Amplifier," poster paper at the Nineteenth International Free Electron Laser Conference, Beijing, China, August 1997.

THESES DIRECTED:

Kesselring, M.D., "Simulations of the LANL 1 kW Regenerative Amplifier FEL," Master's Thesis, Naval Postgraduate School, September 1997.

Nguyen, R.T., "Simulations of the LANL 1 kW Regenerative MW Free Electron Laser Amplifier," Master's Thesis, Naval Postgraduate School, March 1997.

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

KEYWORDS: Free Electron Laser, High Energy Laser

REMOTE SENSING - POLARIZATION EFFECTS IN THE INFRARED

Alfred W. M. Cooper, Professor

Department of Physics

Sponsors: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: To develop instrumentation and techniques for measurement of environmental factors needed for prediction, analysis, and modeling of infrared sensor performance in the marine boundary layer. This includes target and background signatures, polarization, and sun glint, and local atmospheric profiles.

SUMMARY: Previous measurements have shown that polarization filtering can improve target/background contrast in infrared imaging. The NPS Split Field Polarimeter and internally mounted polarizers were used in the EOPACE measurement series (San Diego, November 1996) to record an extensive database of sea, shore, and ship imagery with vertical and horizontal polarizations. Laboratory calibration characteristics were determined for the split-field images for the new Cedip 12 bit data acquisition software, for comparison with in-scene reference sources. A simple polarization-dependent quantitative range prediction model has been developed to evaluate polarization influence on target detection range. The image database was catalogued and image sets selected for further quantitative analysis. The polarimeter has been adapted for use with a 10X large aperture telescope for resolution of 0.1 mrad.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments, Electronic Warfare.

KEYWORDS: Atmospheric Optics, Infrared Sensors, IRST

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SHIP SIGNATURES AND TARGET DETECTION—DETECTION AND RECOGNITION CRITERIA IN FLIR TDA

Alfred W. M. Cooper, Professor
Department of Physics

Sponsors: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: To improve the prediction of detection range for infrared signatures through evaluation of environmentally modified ship signatures and experimental evaluation of criteria for detection and recognition.

SUMMARY: Physical and meteorological parameters selected from the database of the EOMET95 Monterey Bay measurements with the research vessel *Point Sur* were used to define a consistent set of conditions for evaluation of range dependent Apparent Contrast Temperature Difference for the ship against the sea background. Maximum detection and recognition ranges were evaluated by comparison of the apparent temperature difference with the required Minimum Detectable and Minimum Resolvable Temperature Difference Modeled (MRTD). Atmospheric correction of contrast using the SEARAD version of MODTRAN was compared with the commonly used Beer's Law form based on an average extinction coefficient. MRTD and MDTD for a generic Common Module FLIR were modeled as functions of range using the Johnson Criterion for detection and a simple ship model. A mounting for insertion of the polarizing beam-splitter coated for the 3-5 micrometer (MWIR) band into the split-field polarimeter has been constructed and a bench setup completed for incorporation of the polarimeter with the large telescope for increasing resolution to 0.1 milliradians. Selection of EOPACE image data for evaluation of detection ranges was initiated but delayed pending correction of instrument-related calibration problems. Processing programs for automatic selection and averaging of target image pixels and background have been written and application begun.

THESIS DIRECTED:

Yu, C.-L., "Estimate of Maximum Detection Range for FLIR from EOMET95 Measurement Data," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Atmospheric Optics, Infrared Sensors, FLIR.

INFRARED SURVEILLANCE AND TARGET DISCRIMINATION RESEARCH

Alfred W. M. Cooper, Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVES: The objectives are: (1) to investigate the influence of atmospheric refraction and turbulence on the detection and location of small near-horizon targets by infrared imaging systems (particularly Thermal Imaging Systems including Infrared Search and Track Systems and FLIR) operating in the marine surface layer and (2) to compare the results with model predictions using LOWTRAN, MODTRAN, and IRTOOL. This is a continuing project.

SUMMARY: A large aperture telescope was modified to operate in conjunction with an AMBER infrared focal plane camera to provide resolution at 0.1 mrad at f/# of 1.8, suitable for measurement of atmospheric refraction and turbulent spread on sea-grazing paths of order 20 km. This will allow measurement in Monterey Bay when the necessary cooperative support measures are available. The IRTOOL system performance simulation code has been installed and operated to predict detection range and apparent target location for an initial set of scenarios based on estimated current generationIRST parameters with low-flying small targets.

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DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments, Electronic Warfare

KEYWORDS: Atmospheric Optics, Infrared Sensors, IRST

DESIGN-DEVELOPMENT OF CONTROL SYSTEM FOR MULTIPLEXED KRONECKER PRODUCT IMAGER

D. Scott Davis, Associate Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: To design a prototype servo control system for precise mask positioning in the Kronecker product multiplexed imager.

SUMMARY: The next-generation medium and far infrared multiplexed imaging system will be based upon the Kronecker product approach invented at the Naval Postgraduate School (D.S. Davis: "Multiplexed Imaging by Means of Optically-generated Kronecker Products: 1. The Basic Concept," *Applied Optics*, pp. 1170 – 1176, 1995). The task completed during this research was the design of the prototype opto-mechanical and opto-electronic servo system which will be responsible for spatial positioning of the instrument's Walsh encoding masks to very fine (micron-tolerance) precision.

PUBLICATION:

Davis, D.S., "Design for a Fully-Multiplexed Imaging Fourier Transform Spectrometer," *Proceedings of the Optical Society of America Technical Digest Series*, pp. 32-34, 1997.

Davis, D.S. "A Fully-Multiplexed Imaging Fourier Transform Spectrometer," *Proceedings of the Optical Society of America Winter Topical Conference*, January 1997.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Infrared, Multiplexing, Imaging, Spectroscopy

COMBAT SYSTEM ELECTROMAGNETIC ENGINEERING

Robert C. Harney, Associate Professor

Department of Physics

Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of this project is to integrate the electromagnetic engineering (EMENG) suite of tools and top-side design principles being developed by the Combat Systems Design and Engineering Group (03K) of NAVSEA into NPS's Total Ship Systems Engineering (TSSE) program. The intent is to educate the TSSE students concerning the need and techniques for improving the electromagnetic characteristics and performance of a surface combatant and to serve as a beta test site for proving out the evolving EMENG suite of computer-aided design tools.

SUMMARY: During 1997 the new Windows NT-compatible version of the EMENG suite of computer-aided design and analysis tools was obtained from NAVSEA. Necessary additional database, X-windows, Fortran compiler, and C++ compiler software was purchased. The NAVSEA-provided Intergraph computer hardware and personal computers running Windows NT have been incorporated into the TSSE laboratory area. A subcontract was placed with Systems Integration and Research, Inc., to provide continuing applications support through June 1998 via the involvement of Frank Fassnacht (the original principal investigator). The process of extracting the minimum required data from the software manuals and condensing it into a form simplified for student assimilation was begun and will continue into early 1998. After generating a simplified user manual, several test cases will be developed for incorporation into the TSSE 4000 (Combat Systems

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Integration) course as student laboratory exercises and into the TS4002/ TS4003 (Capstone Ship Design Project) courses as design tools. The laboratory exercises will demonstrate to the students the use of each of the key functional aspects of the EMENG software suite that they will need to use in the Capstone Ship Design Project.

DoD KEY TECHNOLOGY AREA: Other (Design Automation)

KEYWORDS: Topside Design, Electromagnetic Interference, Electromagnetic Engineering, Computer-Aided Design, Total Ship Systems Engineering, Combat System Engineering

INVESTIGATION OF HARD KILL-SOFT KILL INTERACTIONS

Robert C. Harney, Associate Professor

Department of Physics

D. Curtis Schleher, Professor

Information Warfare Academic Group

Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of this project is to investigate the interactions of soft-kill weapons (jammers, decoys, etc.) with hard-kill weapons (guns, interceptor missiles, etc.) in an air defense environment. This project will identify and catalog all potential interaction of each soft-kill system with each hard-kill system (and vice versa), so that the information can be properly incorporated into self-defense systems.

SUMMARY: Existing and advanced developmental hard-kill and soft-kill systems have been identified as have the most serious missile threats. Each system has been evaluated for any effect it may have on any other of the identified systems. A considerable number of potentially serious interactions have now been identified. For example, chaff is a useful decoy against some active radar missile seekers. However, after chaff is deployed, it will reflect signals from many radars. Missile seeker radar signals will be reflected into electronic support (ES) receivers producing false missile targets in the ES system. This may potentially degrade the performance of jammers or the performance of semiactive guided interceptors by misdirecting the jamming or illuminator beams (which are pointed by the ES system). Tracking radar signals reflected from the chaff may degrade the tracking performance of those radars. The interactions identified in this work can have significant impacts on the utilization of defensive assets. For example, the chaff-radar interaction may further limit the choice of locations relative to the ship for chaff employment (they are already limited by decoy effectiveness), and it may require inputting the selected location into the ES system processor (so that "targets" in that direction are ignored). These interactions and their potential effects have been catalogued and are being documented in the final report. In potential follow-ons to this work it is hoped to quantify the magnitudes of effects resulting from the identified interactions, to thereby determine which interactions are significant and which may be effectively ignored, and to devise strategies for optimizing the performance of the combined defensive systems.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Electronic Combat, Countermeasures, Air Defense Weapons, Hard Kill, Soft Kill

DEVELOPMENT OF LASER AND LIDAR TECHNOLOGIES

Robert C. Harney, Associate Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this project is to establish a laboratory suitable for the development of novel laser sources for lidar (laser radar) systems and studying the applications of laser and lidar technologies to military problems. Specific objectives include demonstration of a simple cw Doppler lidar for remote sensing of vibrations suitable for measurements in support of concept development and subsequent proposals, assembly of a backscatter lidar that can be used for aerosol

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profiling, and development of novel laser sources for upgrading these lidars as well as incorporation into new lidar applications.

SUMMARY: During 1997 the assembly of a breadboard, cw Doppler lidar (including laser, detector, acousto-optic modulator, optics, and rf electronics) was completed. The performance of this lidar in detecting vibrations was verified in the laboratory using a special calibration source assembled during 1996 under this task. The design, assembly, and performance verification was documented in a thesis published in March 1997 by CPT Jim Day. CPT Day's data was obtained using an analog spectrum analyzer borrowed from another researcher. Processing of the data was limited to those modes implemented in the hardware. Data archival was limited to a paper printout. To facilitate more extensive digital signal processing as well as digital data storage for archival purposes and to create a system independent of borrowed equipment, a personal computer-based digital data acquisition and processing system was procured. This system was integrated with the lidar hardware and work on programming a virtual spectrum analyzer into the computer using the LabView software system was begun. This work is being performed by LCDR Felix Montez and will be documented in his thesis to be finished in June 1998.

Follow-on efforts to this work are expected to be funded by other sources and are strongly dependent on student interest and participation. Most probable will be the repackaging of the breadboard optical system into a more compact and rugged design suitable for field measurements. All components anticipated for this activity are now on hand. A third student has indicated tentative interest but has not yet submitted a formal thesis proposal.

In addition to the Doppler lidar efforts described above, further equipment was procured to facilitate development of other laser and lidar projects. A high-prf green laser, narrowband filters, and scanning optics have been procured for an aerosol backscatter lidar. Flashlamps and optical mounts have been procured to facilitate development of a tunable laser source for a differential absorption lidar.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: LIDAR, Remote Sensing

IMPROVED EFFICIENCY AND POWER DENSITY FOR THERMOACOUSTIC COOLERS

Thomas J. Hofler, Associate Professor

Department of Physics

Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To perform basic research on thermoacoustic cooling processes for applications requiring high cooling power and a small temperature span. The specific focus is on a heat driven cooling engine with no moving parts. This system could use a waste heat source such as the gas turbine exhaust on a Navy surface vessel.

SUMMARY: Previously, a laboratory prototype cooling engine of a new design was modeled numerically, partially optimized, and constructed. The prototype has produced much data in 1997 on a variety of thermoacoustic stacks and resonator tuning combinations.

The numerical model predicts stability/onset criteria for acoustic oscillations that are very sensitive to the temperature distribution of the resonator. This has been borne out experimentally and is utilized to thermally tune the engine to facilitate start-up, without adding moving parts. Thermal tuning is a big advantage of the current design, eliminating the need for excessively high temperatures.

A variety of new stack structures have been successfully tested in the engine. Stacks made from randomly oriented stainless steel wire mesh, random porous carbon foam, and rolled stainless steel foil, have produced good performance, with varying characteristics.

The design model predicted performance numbers of 500 W of cooling power at a temperature span of 40° C, for 1160 W of heat input, yielding an overall coefficient-of-performance of COP = 43%. In June, the engine first produced good refrigeration, and the best performance numbers are as follows: A maximum refrigerated temperature span of 65° C; and a maximum cooling power of 91W at a span of 25° C, for a COP of 15%.

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In short, the performance shows good temperature span, with significant but modest power and efficiency. The power level is commensurate with the acoustic amplitude which is half of the anticipated design value. It is also known that the heat exchangers are limiting both power and efficiency, and the stacks are perhaps limiting efficiency. Also, the operation of the engine appears to be very simple, stable, and free from any known reliability problems. Audible noise from the engine is significant at about 70 dBA. Recently, the analysis and design of the engine has been modified to achieve vibration cancellation. The hope is for a noise reduction of 20 dB or more, when the new modifications are tested.

PUBLICATIONS:

Adeff, J.A., Hofler, T.J., Atchley, A.A., and Moss, W.C., "Measurements with Reticulated Vitreous Carbon Stacks in Thermoacoustic Prime Movers and Refrigerators," *Journal of the Acoustical Society of America*, accepted for publication.

Hofler, T.J. and Adeff, J.A., "Improvements in an Experimental Thermoacoustically Driven Thermoacoustic Refrigerator," *Journal of the Acoustical Society of America*, Vol. 102, No. 5, Pt. 2, p. 3071, San Diego, CA, November 1997.

Hofler, T.J., Adeff, J.A., and Atchley, A.A., "Experimental Results with a Thermoacoustically Driven Thermoacoustic Refrigerator," *Journal of the Acoustical Society of America*, Vol. 101, No. 5 Pt. 2, p. 3021, State College, PA, June 1997.

CONFERENCE PRESENTATIONS:

Hofler, T.J. and Adeff, J.A., "Improvements in an Experimental Thermoacoustically Driven Thermoacoustic Refrigerator," Acoustical Society of America, San Diego, CA, November 1997.

Hofler, T.J., Adeff, J.A., and Atchley, A.A., "Experimental Results with a Thermoacoustically Driven Thermoacoustic Refrigerator," Acoustical Society of America, State College, PA, June 1997.

DoD KEY TECHNOLOGY AREA: Other (Energy Conversion)

KEYWORDS: Thermoacoustic, Refrigeration, Cooler

ACOUSTIC ANALOGS TO ELECTROMAGNETIC ZERO POINT FIELD EFFECTS

Andrés Larraza, Assistant Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: To establish basic experimental and theoretical research on acoustic analogs to effects predicted from the properties of the electromagnetic zero point field (ZPF). This new area of research has the potential to test a broad array of new concepts where the ZPF may play a major role, including inertia, gravitation, and sonoluminescence. The use of broadband noise in the acoustic analog to the Casimir effect may lead to non-resonant acoustic levitation and manipulation.

SUMMARY: Theoretical and experimental results were obtained for the force law between two rigid, parallel plates due to the radiation pressure of broadband acoustic noise. The noise is in the band of 5 to 15 kHz and has an intensity of 133 dB (re 10^{-12} W/m²). Excellent agreement is shown between theory and experiment. These results constitute an acoustic analog for the Casimir effect, which is the force experienced by two closely spaced uncharged conducting plates due to the quantum electromagnetic zero point field. In contrast to this case, however, band limited noise can cause the force to be *attractive* or *repulsive* as a function of separation between the plates. Applications of the acoustic Casimir effect to noise transduction can provide new means to measure background noise. Because attractive or repulsive forces can be obtained by adjusting the noise spectrum or the plate geometry, a non-resonant method of acoustic levitation can also be possible.

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PUBLICATIONS:

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "The Force of Attraction Between Two Parallel Rigid Plates due to the Radiation Pressure of Broadband Noise: An Acoustic Casimir Effect," accepted for publication in the *Journal of the Acoustical Society of America*.

Larraza, A. and Denardo, B., "An Acoustic Casimir Effect," submitted.

CONFERENCE PRESENTATIONS:

Larraza, A., "Some Acoustic Analogs to Electromagnetic Zero Point Field Effects: Static and Dynamic Acoustic Casimir Effects," *Quantum Aspects of Beam Physics*, Monterey, CA, January 1998.

Simmons, T., Denardo, B., Larraza, A., and Keolian, R., "An Acoustic Radiometer," Acoustical Society of America Meeting, June 1998.

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "An Acoustic Casimir Effect, Acoustical Society of America Meeting, June 1998.

Larraza, A., "An Acoustic Casimir Effect," Department of Physics Colloquium, Naval Postgraduate School, 15 August 1997.

THESIS DIRECTED:

Holmes, C.D., "Acoustic Casimir Effect," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Electromagnetic Zero Point Field, Random Waves, Linear Acoustics

INVESTIGATIONS OF NONLINEAR ACOUSTIC NOISE

Andrés Larraza, Assistant Professor

Department of Physics

Sponsor: University of Mississippi

OBJECTIVE: To perform experimental and numerical investigations of the effect on a signal due to interactions with intense noise. Both, the effect of reducing the bandwidth of the noise while keeping the noise intensity constant and the effect of band-limited periodic noise will be investigated. Further properties of the nonlinear noise, including downstream injection of the signal and the possibility of collective modes, will also be investigated numerically.

SUMMARY: Nonlinear noise can probe the nature of systems driven far off equilibrium. This was established by measurements that probe the Gaussian nature of the absorption of sound by noise in one dimension and by observations of the power law spectrum of fully developed shockless noise. The Gaussian attenuation of a monochromatic signal in the presence of discrete noise in one dimension has been numerically verified. Two new results have also been uncovered. In the first, a transition was observed from Gaussian to Bessel dependence as a function of resolution in the detection of a signal. This result shows that the fundamental property of time reversibility can only be established if the overall system of the waves and the observer is considered. In the second result, the evolution was investigated of the amplitude of a signal injected downstream from the noise. Again the Gaussian attenuation was observed. This result explicitly shows that the attenuation length depends on the distance the signal has traveled, thus displaying memory and breakdown of translational invariance. Additionally, numerical and analytical searches for collective modes are currently being performed for shockless and shock noise, respectively. Although such modes in far off equilibrium noise have been predicted in several systems, there are

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currently no controlled observations. These modes are important, for example, as a mechanism of energy transfer. If this behavior is numerically or analytically indicated for one-dimensional acoustics, it will be experimentally established. Besides probing a variety of fundamental issues, our nonlinear noise research may have applications to noise generation and control, especially in regard to supersonic vehicles. An understanding may lead to techniques to actively suppress the development of shocks.

PUBLICATIONS:

Larraza, A. and Denardo, B., "Acoustic Waveguides as Tools in Fundamental Nonlinear Physics," eds: Phillip F. Schewe and Ben P. Stein, *Physics News in 1996*, pp. 2-3, American Institute of Physics, College Park, MD, 1997.

Larraza, A. and Denardo, B., "Acoustic Waveguides as Tools in Fundamental Nonlinear Physics," *Journal of the Acoustical Society of America*, 101 1997.

Mital, V., Denardo, B., Jang, H., and Larraza, A., "Numerical Simulations of the Absorption of Sound by Noise in One Dimension," *Journal of the Acoustical Society of America*, 101, No. 5, Pt. 2, 3080, 1997.

CONFERENCE PRESENTATION:

Mital, V., Denardo, B., Jang, H., and Larraza, A., "Numerical Simulations of the Absorption of Sound by Noise in One Dimension," Acoustical Society of America, State College, PA, 1997.

THESES DIRECTED:

Lamczyk, M. and Park, J., "Experimental and Theoretical Investigations of the Gaussian Suppression of Sound by Sound," Master's Thesis, Naval Postgraduate School, June 1997.

Mital, V., "Numerical Simulations of the Absorption of Sound by Noise in One Dimension," Master's Thesis, University of Mississippi, August 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Nonlinear Waves, Random Waves.

DEVELOPMENT OF QUANTUM DEVICE MODELS

James H. Luscombe, Associate Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this program is to develop theoretical models of the electronic, magnetic, and structural properties of materials and systems at the nanometer length scale. While the primary emphasis is on developing models of heterostructure quantum electron devices, there is also interest in nano-scale magnetic systems. This is a continuing project.

SUMMARY: There were two separate thrusts to the research this year: (1) To examine theoretically the effects of deliberate compositional modifications to semiconductor superlattices on electron dynamics. The insights gained were then used to develop a proposal for a spatially selective photo-excitation process that would reduce the dephasing of Bloch oscillation signals, and hence lead to significantly longer-lived Bloch oscillations. Bloch oscillations in semiconductor superlattices are a possible means of generating TeraHertz electromagnetic radiation. (2) Models were developed of the magnetic properties of recently synthesized molecular clusters containing a relatively small number (4-10) of magnetic atoms. A classical spin model was developed to predict the magnetic susceptibility and compared with recent experimental data. The insights gained from this theory were used to develop a model of the nuclear-magnetic-resonance (NMR) spin-lattice

PROJECT SUMMARIES

relaxation time in small magnetic clusters. Magnetic molecular clusters have possible applications as ultra-dense information storage systems.

PUBLICATIONS:

Borsa, F., Jang, Z., Shastri, A., Luban, M., Lascialfari, A., Gatteschi, D. and Luscombe, J.H., "Proton Spin-Lattice Relaxation and Spin Dynamics in Magnetic Molecular Clusters," *Bulletin of the American Physical Society*, Vol. 42, p. 731, 1997.

Luban, M. and Luscombe, J.H., "Dynamical Localization of Electrons in Aperiodic Superlattices," *Physical Review B*, accepted for publication.

Luban, M., Reynolds, J.P., and Luscombe, J.H., "Enhanced Lifetimes of Bloch Oscillations by Spatially Selective Photoexcitation," *Proceedings of the International Semiconductor Device Research Symposium*, Vol. 4, p. 533-537, 1997.

Luscombe, J.H. and Luban, M., "Wave-Vector-Dependent Magnetic Susceptibility of Classical Heisenberg Rings," *Journal of Physics: Condensed Matter*, Vol. 9, p. 6913-20, 1997.

Luscombe, J.H. and Luban, M., "Classical Heisenberg Model of Magnetic Molecular Ring Clusters: Accurate Approximates for Correlation Functions and Susceptibility," *Journal of Chemical Physics*, accepted for publication.

Luscombe, J.H., Luban, M., and Borsa, F., "Classical Heisenberg Model of a Ring Nanostructure: Correlation Functions and Susceptibility," *Bulletin of the American Physical Society*, Vol. 42, p. 258, 1997.

Reynolds, J.P., Luban, M., and Luscombe, J.H., "Long-Lived Quasi-Periodic Bloch Oscillations by Spatially Selective Photoexcitation," *Bulletin of the American Physical Society*, Vol. 42, p. 607, 1997.

CONFERENCE PRESENTATIONS:

Borsa, F., Jang, Z., Shastri, A., Luban, M., Lascialfari, A., Gatteschi, D., and Luscombe, J.H., "Proton Spin-Lattice Relaxation and Spin Dynamics in Magnetic Molecular Clusters," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

Luban, M., Jang, Z., and Luscombe, J.H., "Proton Spin-Lattice Relaxation Rate for Magnetic Molecular Ring Clusters," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1997.

Luban, M., Reynolds, J.P., and Luscombe, J.H., "Enhanced Lifetimes of Bloch Oscillations by Spatially Selective Photoexcitation," International Semiconductor Device Research Symposium, Charlottesville, VA, 11-13 December 1997.

Luscombe, J.H., Luban, M., and Borsa, F., "Classical Heisenberg Model of a Ring Nanostructure: Correlation Functions and Susceptibility," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

Luscombe, J.H., "Nano-Scale Electronics for the 21st Century," Innovation and Defense Technology 2020, Pacific Grove, CA, 1-4 December 1997.

Luscombe, J.H., Luban, M., and Reynolds, J.P., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1998.

Reynolds, J.P., Luban, M., and Luscombe, J.H., "Long-Lived Quasi-Periodic Bloch Oscillations by Spatially Selective Photoexcitation," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

PROJECT SUMMARIES

THESES DIRECTED:

Johnson, B., "Numerical Acceleration of the Mie Scattering Series," Master's Thesis, Naval Postgraduate School, December 1997.

Kruppa, S., "Modeling Quantum-Dot Devices," Master's Thesis, Naval Postgraduate School, June 1997.

Spencer, F., "High-Precision Computational Method for the Quantum Transmission Coefficient," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Electronics, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Nanoelectronics, Nanotechnology, Nanomagnetism

TESTING AND CHARACTERIZATION OF A ONE-METER ELECTROMAGNETIC RAILGUN

William B. Maier, Senior Lecturer

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: The purpose of this research is to discover the operating parameters, e.g., current pulse shape, that maximize the efficiency with which energy is transferred to the railgun projectile. The information would be used to optimize railgun operation.

SUMMARY: Railgun theory and practice have been reexamined to determine the best current shape for the current pulse driving a railgun projectile. The approach to this problem has been primarily theoretical. The capacitors for the one-meter railgun failed early in the year, so the experiment was transferred to a smaller device. At the same time, the effect of current pulse shape on projectile velocity was studied theoretically. The results show that the dependence on current pulse shape depends in turn on the mechanisms by which energy is dissipated in the system.

DoD KEY TECHNOLOGY AREA: Conventional Weapons

KEYWORDS: Electromagnetic Railgun, Projectile Velocities

THESIS DIRECTED:

Hartke, J.P., "Characterization and Magnetic Augmentation of a Low Voltage Electromagnetic Railgun," Master's Thesis, Naval Postgraduate School, December 1997.

RADIATION SOURCES AT THE NAVAL POSTGRADUATE SCHOOL

Xavier K. Maruyama, Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: The radiation sources at NPS, the 100 MeV RF electron linear accelerator and the 1.7 MV pulsed flash x-ray machine, are required for a number of projects at NPS including the study of unipolar arcing plasma physics, investigation of novel sources of coherent radiation and radiation effects in materials and electronic devices. In addition, there are radioactive sources, which are primarily used for detector calibration and for classroom laboratories and demonstration. These are available to a variety of investigators from the Naval Postgraduate School and their associated external collabo-

PROJECT SUMMARIES

rators. In addition to the use as radiation sources, the facility capabilities are maintained to provide NPS with resources for pulsed power technology.

SUMMARY: The works cited here arise from activities of this present year and from past years. Experiments leading to publication in high-energy physics is not currently being pursued, but the product of previous years endeavors are continuing. Contributions were made to the E143 collaboration at SLAC which is an important effort to understand the underlying quark structure of nucleons and within nuclei.

Study of photon generation mechanisms to produce x-rays for application such as photolithography. Transition and parametric radiation investigation continue. In addition, x-ray optics was investigated using polycapillary lenses.

Collaborative efforts with students in a nuclear physics laboratory course led to a here-to-for uninvestigated study of the radioactive glaze in collectible chinaware. This study is truly multidisciplinary in that radiation physics, Manhattan Project era political history and knowledge of American antiques and collectibles were necessary to create a method to differentiate pre- and post- World War II American chinaware.

Because the radiation sources can be viewed as a school resource, not all work associated with this effort are reported here. In particular, Associate Professor Sheriff Michael of the Department of Electrical and Computer Engineering, conducted experiments with thesis students in radiation effects on fault tolerant circuits and CPT John Hartke, USA, did his thesis work concerning railgun technology using the resources of the radiation facilities.

PUBLICATIONS:

Abe, K., Akagi, T., Anthony, P.L., Antonov, R., Arnold, R.G., Averett, T., Band, H.R., Bauer, J.M., Borel, H., Bosted, P.E., Breton, V., Button-Shafer, J., Chen, J.P., Chupp, T.E., Cledenin, J., Comptour, C., Coulter, K.P., Court, G., Crabb, D., Daoudi, M., Day, D., Dietrich, F.S., Day, D., Dietrich, F.S., Dunne, J., Dutz, H., Erbacher, R., Fellbaum, J., Feltham, A., Fonvieille, H., Friez, E., Garvey, D., Gearhart, R., Gomez, J., Grenier, P., Griffioen, K.A., Hoibraten, S., Hughes, E.W., Hyde-Wright, C., Johnson, J.R., Kawall, D., Klein, A., Kuhn, S.E., Kuriki, M., Lindgren, R., Liu, T.J., Lombard-Nelsen, R.M., Marroncle, J., Maruyama, X.K. McCarthy, J., Meyer, W., Meziani, Z.E., Minehart, R., Mitchell, J., Morgenstern, J., Petratos, G.C., Pitthan, R., Pocanic, D., Prescott, C., Prepost, R., Raines, P., Raue, B., Reyna, D., Rijllart, A., Roblin, Y., Rochester, L., Rock, S.E., Rondon, O.A., Sick, I., Smith, L.C., Smith, T.B., Spengos, M., Staley, F., Steiner, P., St. Lorant S., Stuart, L.M., Suekane, F., Szalata, Z.M., Tang, H., Terrien, Y., Usher, T., Walz, D., White, J.L.K., Witte, K., Young, C., Youngman, B., Yuta, H., Zapalac, G., Zihlmann, B., Zimmerman, D., (The E143 Collaboration), "Measurement of the Proton and Deuteron Spin Structure Function g_1 in the Resonance Region," *Physical Review Letters* 78, 815, 1997.

Piestrup, M.A., Powell, M.W., Mrowka, S., Lombardo, L.W., Chase, M.B., Cremer, J.T. and Maruyama, X.K., "A Single-Stepper Soft-X-Ray Source for Step-and-Scan Tools," *SPIE*, Vol. 3048, pp.176-182, 1997.

Piestrup, M.A., Powell, W.W., Mrowka, S., Cremer, J.T., Lombardo, L.W., Chase, M.B., Snyder, D., Rietdyk, H., and Maruyama, X.K., "A Transition Radiation Source with a Grazing Angle Optic for Step and Scan Lithography," *Proceedings of the International Symposium on Radiation of Relativistic Electrons in Periodical Structures*, RREPS-97, Tomsk, Russia, September 1997.

Schagin, A.V. and Maruyama, X.K., "Parametric X Rays," Chapter 9, *Accelerator-Based Atomic Physics Techniques and Applications*, pp. 279-307, Stephen M. Shafroth and James C. Austin (eds), American Institute of Physics, 1997.

CONFERENCE PRESENTATIONS:

Alba, A., Hartke, J., Chase, M., Hooks, T.A., Rietdyk, H., Snyder, D., Maruyama, X.K., "Effect of Nuclear Weapons on Red China," Joint Southern California and Northern California/Nevada Spring 1997 Meeting, American Association of Physics Teachers, Cal Poly, San Luis Obispo, CA, 25-26 April 1997.

Piestrup, M.A., Powell, W.W., Mrowka, S., Cremer, J.T., Lombardo, L.W., Chase, M.B., Snyder, D., Rietdyk, H., and Maruyama, X.K., "A Transition Radiation Source with a Grazing Angle Optic for Step and Scan Lithography," Interna-

PROJECT SUMMARIES

tional Symposium on Radiation of Relativistic Electrons in Periodical Structures, RREPS-97, Tomsk, Russia, September 1997.

Piestrup, M.A., Powell, M.W., Mrowka, S., Lombardo, L.W., Chase, M.B., Cremer, J.T., Maruyama, X.K., "A Single-Stepper Soft-X-Ray Source for Step-and-Scan Tools," SPIE, San Francisco, CA, March 1997.

THESIS DIRECTED:

Chase, M.B., "Boro-Silicate Polycapillary Lens for Collimation of X-Rays," Master's Thesis, Naval Postgraduate School, June 1997.

OTHER:

Maruyama, X.K., "The Effect of Nuclear Weapons on Red China or How the Manhattan Project Changed the Red Glaze on Ceramics," Department of Physics, Naval Postgraduate School, Monterey, CA, 16 May 1997, colloquium.

DoD KEY TECHNOLOGY AREA: Other (Radiation)

KEYWORDS: Accelerator, Klystron, Linac, Flash X-Ray, Radiation, Parametric X-Ray, Railgun, Radiation Effects

TECHNOLOGIES FOR OPERATIONS OTHER THAN WAR

**Xavier K. Maruyama, Professor
Department of Physics**

Sponsor: Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVE: This project is to investigate the technological innovation and their implications for Military Operations Other Than War (MOOTW). In particular, non-lethal weaponry, mine detection, demining, sniper and anti-sniper technologies, vehicle add on armor and individual soldier communications are technologies which are necessary for major regional conflicts, but have implications in MOOTW.

SUMMARY: Assessment of technologies applicable to MOOTW has been conducted. In addition, the relationship between these technologies and other civil-military areas of concern, such as aviation security, weapons of mass destruction and terrorism have been explored. By their nature, MOOTW requires interservice and multilateral cooperation. This program allows for participation in mine detection and clearance efforts.

This program initiated involvement in aviation security and local emergency response activities. The involvement in aviation security has led to a separate FAA sponsored project discussed below. The local emergency response involvement has led to a separate activity concerning response to chem-bio terrorism events.

PUBLICATION:

Maruyama, X.K., Cochran, T.B., Norris, R.S., and Bukharin, O.A., "Making the Russian Bomb, From Stalin to Yeltsin," book review for *Naval War College Review*, p. 159, Winter 1997, Vol. L, No. 1, Sequence 357.

OTHER:

Shaw, A., Fainberg, T., and Maruyama, X.K., "Technologies for Peace Support Operations," Congressional Research Service Seminar, Library of Congress, Washington DC, 8 January 1997.

PROJECT SUMMARIES

THESIS DIRECTED:

Leonardy, T., "Implementation and Evaluation of an INS System for the Shepherd Rotary Vehicle," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Other (Non-Lethal Weapons)

KEYWORDS: MOOTW, WMD

BIOLOGICAL AND CHEMICAL TERRORISM AND ASSESSMENT, LOCAL AND NATIONAL RESPONSE COORDINATION

**Xavier K. Maruyama, Professor
Department of Physics**

Sponsor: Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVE: The purpose of this program is to increase our understanding of and improve our response mechanisms in the event of biological or chemical terrorism. The immediate response will depend on the ability of local emergency agencies to cope with the act. Consequently, it is critical to understand local emergency response mechanisms. A computer model will be created with input data taken from actual events and/or drill exercises.

SUMMARY: This work studied the local emergency response mechanism. A major multi-casualty incident, MCI, drill was conducted on 22 November 1997 in which over 170 people participated including, 60 victims, 10 fire trucks, 4 ambulances, a helicopter and 30 data collectors in addition to other personnel. Our role was to take data during a multi-casualty incident in order to quantify the local emergency response mechanism. This data will be incorporated into models to investigate the role of local emergency response units in a chem-bio WMD terrorism incident. A report concerning the 22 November 1997 Pacific Grove, CA, MCI drill will be issued in winter 1998 as an Institute for Joint Warfare Analysis report. This work is partially the results of earlier efforts in studying MOOTW.

DoD KEY TECHNOLOGY AREA: Other (Terrorism)

KEYWORDS: Biological or Chemical Terrorism, MOOTW

AVIATION SAFETY/ SECURITY TECHNOLOGY ASSESSMENT

**Xavier K. Maruyama, Professor
Department of Physics**

**Sponsors: Federal Aviation Agency and
Naval Postgraduate School-Institute of Joint Warfare Analysis**

OBJECTIVE: The White House Commission on Aviation and Security has recommended the deployment of existing technology and establishment of research and development programs to enhance the security of air travel. This proposal is to assess technologies relating to explosive detection in cargo, checked baggage, carry-on bags, and passengers, in a language which airline executives and day-to-day operators can understand. The final report will enable the airline operators to understand the scientific and engineering basis for the various technologies so that they may better evaluate the strengths and weaknesses of existing and developing technologies.

SUMMARY: The project is in the exploratory stage. The subject matter for this project is intimately related to the previous projects, concerning military operations other than war (MOOTW) and response to terrorism. Preliminary work related to this project was begun under the auspices of the Institute of Joint Warfare Analysis.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREA: Other (Security)

KEYWORDS: MOOTW, Air Travel, Terrorism

OPERATIONAL FEASIBILITY OF RIGID FOAM AS A MINE COUNTERMEASURE

Xavier K. Maruyama, Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To determine the operational feasibility of the use of rigid foam for countermine use. Rigid foam has been shown in the laboratory to be feasible for absorbing mine blast and for distributing weight sufficiently to allow vehicles and personnel to transit over explosives. The research will address technical and operational issues on the use of rigid foam. A technical curriculum army student has committed to work on this thesis arena. If this effort has support, at least one other student will be recruited, preferably from the Special Operations Arena to look at scenario driven operational issues.

SUMMARY: Experiments were conducted at Waterways Experimental Station, Vicksburg, MS, and Energetic Materials Research and Testing Center, Socorro, NM, to investigate the feasibility of using rigid polyurethane foam (RPF), for operational countermine use. RPF can withstand the explosive effects of anti-personnel blast mines and mitigate or neutralize the effects of surface laid anti-vehicular mines. This work was done as part of a larger effort conducted by Sandia National Laboratories. Results will be presented in the 1998 Mine Technology Symposium, Monterey, CA, April 1998.

THESIS DIRECTED:

Alba, A.L., "Rigid Polyurethane Foam as a Breaching Technique for Anti-Personnel Mines," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Other (Mine Warfare)

KEYWORDS: Mine Countermeasures

LIQUID METAL ION GUN FLIGHT EXPERIMENT

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: National Aeronautics and Space Administration-Goddard Space Flight Center

OBJECTIVE: Prepare charge control experiment for launch on the European Space Agency (ESA) Cluster satellite mission. NPS responsibilities are to procure tile substrate and support charging analysis.

SUMMARY: The project had a small setback when the Ariane V launch vehicle blew up in February 1996. ESA initiated a recovery effort involving utilization of the flight spare instruments for a near-term flight, and construction of four replacement satellites. Fresh tile materials were provided for the construction of a new instrument.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Charging, Ion Beams, Spacecraft-Environment Interactions

PROJECT SUMMARIES

APPLICATION OF HYPERSPECTRAL IMAGING TO NAVAL APPLICATIONS

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: Naval Research Laboratory

OBJECTIVE: To address the application of multispectral and hyperspectral imaging to naval needs and to participate in activities utilizing HYDICE and other instruments, and analyze data collected during these experiments.

SUMMARY: Hyperspectral image data have been acquired from experimental sensors and are being analyzed using non-literal techniques. The objectives are to identify target signatures and other features of interest in land and littoral scenes. Data from HYMSMO projects have been analyzed. Students participated in data collections with HYDICE and other systems.

PUBLICATIONS:

Collins, B.H., Olsen, R.C., and Hackwell, J., "Thermal Imagery Spectral Analysis," *Proceedings of Imaging Spectrometry III, SPIE*, Vol., 3118, pp. 94-105, 1997.

Olsen, R.C., Bergman, S., and Resmini, R.C., "Target Detection in a Forest Environment Using Spectral Imagery," *Proceedings of Imaging Spectrometry III, SPIE*, Vol. 3118, pp. 46-56, 1997.

CONFERENCE PRESENTATIONS:

Collins, B.H., Olsen, R.C., and Hackwell, J., "Thermal Imagery Spectral Analysis," Imaging Spectrometry III, SPIE Annual Meeting, San Diego, CA, 28-30 July 1997.

Olsen, R., Bergman, C.S., and Resmini, R.C., "Target Detection in a Forest Environment Using Spectral Imagery," SPIE Annual Meeting, San Diego, CA, 28-30 July 1997.

THESIS DIRECTED:

Stefanou, M.S., "A Signal Processing Perspective of Hyperspectral Imagery Analysis Techniques," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, Targeting, Trafficability

INFRARED SUBMARINE STUDIES

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: Study the infrared measurements of submarines.

SUMMARY: Data from national systems were analyzed. Results are being transferred to operational intelligence commands.

THESIS DIRECTED:

Deans, K., "Thermal Imagery of Submarines," Master's Thesis, Naval Postgraduate School, September 1997.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, National Systems, ASW, TENCAP

POLAR SATELLITE FLIGHT EXPERIMENT

Richard C. Olsen, Associate Professor

Department of Physics

Sponsor: National Aeronautics and Space Administration-Marshall Space Flight Center

OBJECTIVE: To analyze data taken during charge control experiments on the NASA POLAR satellite mission.

SUMMARY: The POLAR satellite was launched on 24 February 1996. The Plasma Source Instrument (PSI) was successfully operated for the first time on 15 April 1996. After a decade of effort, the plasma source performed as intended, grounding the satellite frame to the ambient plasma potential. This allowed highly sensitive measurements of the ambient plasma characteristics to be made. Data from all the 1996 and early 1997 experiments were analyzed in a special class offering of a class in spacecraft-environment interactions.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Charging, Spacecraft-Environment Interactions

VOLCANIC ASH DRIFT

Richard C. Olsen, Associate Professor

Department of Physics

Sponsors: U.S. Geological Survey and Naval Postgraduate School

OBJECTIVE: The proposal is to enhance model based ash drift forecasts using near real time observations. Products derived from classified and unclassified systems will be used to provide model input. Campaign strategies will be developed for acquisition of necessary "ground truth" information.

SUMMARY: Volcanic ash clouds are a hazard for civil and military aircraft. The ability to identify the boundaries of hazardous regions requires both observations and models of ash cloud behavior. In the first year of study, data from the AVHRR sensor was analyzed. AVHRR data were acquired for volcanic events on the Kamchatka peninsula. Software was developed for the analysis of such data, in order to distinguish between ash and water clouds. These data were compared with observations from national systems, which showed agreement at some times, but "false alarms" at others. The Cobra Brass sensor launched in late 1997 will provide a complementary data set which should enable real-time warnings and model input. Analysis of Cobra Brass data will begin in 1998.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environment

KEYWORDS: Remote Sensing, Environmental Monitoring

PROJECT SUMMARIES

COOPERATIVE DEVELOPMENT OF HUMANITARIAN ASSISTANCE/DISASTER RELIEF OPERATIONS HA/DR

**Gordon Schacher, Professor
Department of Physics**

Sponsor: Tripler Army Medical Center

OBJECTIVE: The modeling and simulation of HA/DR response and mitigation is not yet well developed and is closely related to chemical/biology incident mitigation modeling. A program of providing the operational research foundation, developing models and engaging in the education/training in Humanitarian Assistance/Disaster Relief (HA/DR) is proposed. The Naval Postgraduate School will provide operations research courses for CEDMHA/PACOM personnel, do research into understanding of the HA/DR activities and consult with CEDMHA in the development of requirements for models to support the CEDMHA mission. Where appropriate NPS will develop models and train personnel in their use and interpretation. NPS will conduct workshops and conferences of experts in modeling to ensure a broad review of the requirements and models.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Humanitarian Assistance, Disaster Relief

BOTTOM REVERBERATION DATA ANALYSIS AND PROPAGATION MODELING OF COMPLEX MULTIPATHS

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

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The scientific objective of this work is to understand the limits of signal resolution imposed by complex forward-propagating multipaths. This will be studied in both deep and shallow water environments with data from the 1993 Acoustic Reverberation Special Research Program (ARSRP) acoustics cruise used to compare deep-water results. Proposed here is a two-year program involving data analysis, model predictions, and the software development to support and improve both.

SUMMARY: High quality acoustic reverberation data was collected during ARSRP's main acoustics cruise in the summer of 1993. The ability to correlate these measured returns with bathymetric features depends on the signal resolution. A study of the effects of multipath propagation on signal resolution is proposed. Analysis of the measured data will provide a means of confirming predictions of these effects. An advanced PE propagation model will be used to quantify these effects in the ARSRP environment. This research is a continuation of a FY96 research project sponsored by Office of Naval Research (ONR). During FY97, a direct comparison between a simpler, CW approach and an advanced, broadband calculation was made to determine the exact influence of such multipath propagation. It was determined that in isolated regions these secondary multipaths can influence the reverberation by as much as 20 dB, but that over most ranges of interest, the simple CW approach works extremely well.

PUBLICATION:

Smith, K.B. and Cushman, E.B., "A Comparison of Quasi-Continuous Wave and Broadband Travel Time Techniques in the Prediction of Long-Range Reverberation," *Journal of the Acoustical Society of America*, 102, pp. 2063- 2071, 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Environmental Effects, Acoustic Reverberation, Sonar Performance)

KEYWORDS: Acoustic Reverberation, Propagation, Multipaths

PROJECT SUMMARIES

AN EXAMINATION OF 3D, BROADBAND ACOUSTIC PROPAGATION PHYSICS IN A LITTORAL OCEAN ENVIRONMENT - AN EXTENSION TO AN ONR PRIMER FIELD STUDY IN THE MID-ATLANTIC BIGHT

Kevin B. Smith, Assistant Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: The scientific objective of this work is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight.

SUMMARY: With the emphasis of undersea warfare (USW) shifting to littoral environments, the understanding and, ultimately, prediction of acoustic propagation in the vicinity of the shelfbreak becomes increasingly important. The sloping bathymetry, the extreme seasonal changes in the vertical sound-speed structure and the significant horizontal variability generated by the shelfbreak front are just a few of the environmental factors that make this problem both interesting and complex. Under the PRIMER initiative, the Office of Naval Research is sponsoring a multi-year study of acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream. The general purpose of this project is to study the effects of the frontal region on acoustic propagation onto the shelf. This research is a complementary study of propagation effects and data analysis. Specifically, the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions shall be addressed. In addition to the experimental components already in place, the deployment of explosive SUS charges were coordinated throughout the area at the beginning and end of the study. The addition of these very broadband sources will provide valuable information on specific frequency dependent phenomena. A major effort this year has been the development of direct techniques to extract information on geo-acoustic parameters from the broadband SUS data and the ambient noise field. Additionally, analysis of the data from moored sources has provided detailed information about plane wave variability due to propagation through this complicated region. Both large-scale water mass motion and tidal influences on the front produce observable effects on the received data.

PUBLICATIONS:

Chiu, C.-S., Smith, K.B., Lynch, J.F., Gawarkiewicz, G.G., Pickart, R.S., Sperry, B., Miller, J.H., and Robinson, A.R., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," *Journal of the Acoustical Society of America*, Vol. 102, p. 3143, 1997.

Gawarkiewicz, G.G., Pickart, R.S., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," *Journal of the Acoustical Society of America*, Vol. 101, p. 3016, 1997.

Smith, K.B., Chiu, C.-S., Miller, J.H., Lynch, J.F., and Gawarkiewicz, G.G., "Three-Dimensional Propagation Effects near the Mid-Atlantic Bight," *Journal of the Acoustical Society of America*, Vol. 102, p. 3143, 1997.

Smith, K.B., "Three-Dimensional Effects on Broadband Pulse Propagation Near Shelfbreaks," *Proceedings of International Conference on Shallow Water Acoustics*, Beijing, China, 21-25 April 1997, in press.

CONFERENCE PRESENTATIONS:

Chiu, C.-S., Smith, K.B., Lynch, J.F., Gawarkiewicz, G.G., Pickart, R.S., Sperry, B., Miller, J.H., and Robinson, A.R., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," Acoustical Society of America, State College, PA, 1997.

Gawarkiewicz, G.G., Pickart, R.S., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," Acoustical Society of America, State College, PA, 1997.

PROJECT SUMMARIES

Smith, K.B., "Three-Dimensional Effects on Broadband Pulse Propagation near Shelfbreaks," International Conference on Shallow Water Acoustics, Beijing, China, 21-25 April 1997.

Smith, K.B., Chiu, C.-S., Miller, J.H., Lynch, J.F., and Gawarkiewicz, G.G., "Three-Dimensional Propagation Effects near the Mid-Atlantic Bight," Acoustical Society of America, State College, PA, 1997.

Smith, K.B. "Analysis of Broadband Propagation in a Highly Variable 3-D Environment Near the Mid-Atlantic Bight," Workshop on Underwater Acoustics, National Taiwan University, Taipei, Taiwan, 10-14 November, 1997.

THESIS DIRECTED:

Sullivan, J., "Analysis of Acoustic Plane-Wave Variability in the Region of the Mid-Atlantic Bight Shelfbreak," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (3-D Acoustic Propagation, Littoral Environments)

KEYWORDS: Acoustic Propagation, Azimuthal Coupling, Littoral Environments

EXAMINATION OF 2-D ENVIRONMENTAL MISMATCH AND 3-D ENVIRONMENTAL VARIABILITY INFLUENCES ON LOCALIZATION

Kevin B. Smith, Assistant Professor

Department of Physics

Sponsors: Naval Undersea Warfare Center-Newport Division and Naval Postgraduate School

OBJECTIVE: The scientific objective of this work is to study both the influence of environmental mismatch and propagation mismatch (2-D versus 3-D) on a simple localization algorithm. Synthetic data will also be provided to other investigators testing different algorithms.

SUMMARY: During FY96, research was conducted at the Naval Postgraduate School to determine the robust aspects of acoustic propagation which can be exploited to successfully localize transient phenomena. These results were based on a simple time-domain autocorrelation matching algorithm applied in a simple, range-independent environment. The previous work was expanded and examination was begun on the influences of more realistic environmental variability. Both the influence of environmental mismatch in a 2-D environment and the influence of propagation mismatch in 3-D varying environments were studied. The focus of this study was an examination of the degradation of localization when environmental parameters are varied relative to the "true" environment used to generate the synthetic "measured" data. These variations were based on realistic uncertainties of environmental quantities. This was done in a range-independent manner by simply changing the values or gradients of the water and/or sediment sound speeds, for example, or changing the depth of the water column or thickness of sediment layers. Range-dependent variations were also considered, specifically internal wave variations in the water column sound speed structure. In addition, each of these synthetic results were provided to other investigators to examine similar issues with different localization algorithms. The format of the synthetic data provided was consistent with realistic platform systems and formatted to interface easily with other software.

PUBLICATION:

Smith, K.B., Brune, J., and Chiu, C.-S., "On the Use of Signal Autocorrelation Matching in Localization Algorithms," *Journal of the Acoustical Society of America*, Vol. 102, p. 3192, 1997.

PROJECT SUMMARIES

CONFERENCE PRESENTATIONS:

Smith, K.B., Chiu, C.-S., and Brune, J., "Variations of Autocorrelation Matching and Experimental Overview," Working Group Seminar on Passive Transient Localization, Naval Undersea Warfare Center-Newport Division, Newport, RI, 14-15 July 1997.

Smith, K.B., Brune, J., and Chiu, C.-S., "On the Use of Signal Autocorrelation Matching in Localization Algorithms," Acoustical Society of America, State College, PA, 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Sensors, Other (Localization)

KEYWORDS: Parabolic Equation Model, Autocorrelation Matching, Matched Field Processing, Transient Localization

BASIC RESEARCH IN BURSTING BUBBLES AND AEROSOL SOURCE FUNCTIONS

Donald E. Spiel, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: The objective of this continuing research is to determine the parameters of bursting ocean bubbles relevant to air-sea interaction and the marine boundary layer. Included are the number, size, and ejection parameters of both jet and film droplets.

SUMMARY: Work on the ejection parameters of jet drops for the bubble size range 0.5 to 3 mm-diameter was completed during 1997. During this year, a hypothesis was advanced to explain the peak in film drop production in the bubble size range 2 to 2.5 mm-diameter was advanced. Measurements of film drop production and theoretical calculations have led to a broad understanding on film drop production.

PUBLICATIONS:

Spiel, D.E., "A Hypothesis Concerning the Peak in Film Drop Production as a Function of Bubble Size," *Journal of Geophysical Research*, 102, 1153-1161, 1997.

Spiel, D.E., "More on the Births of Jet Drops from Bubbles Bursting on Seawater Surfaces," *Journal of Geophysical Research*, 102, 5815-5821, 1997.

DOD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Air-Sea Interaction, Jet Drops, Film Drops, Aerosols, Gas Exchange

ATMOSPHERIC OPTICAL TURBULENCE MEASUREMENTS

Donald L. Walters, Associate Professor

Department of Physics

Sponsor: U.S. Air Force Space and Missile Command-Phillips Laboratory

OBJECTIVE: To provide atmospheric optical measurements and consultation for programs of national interest.

SUMMARY: As an active member of U.S. government atmospheric working group team, reviewed government and civilian contractor programs of national interest in over one dozen meetings in Washington DC, Los Angeles, CA, and Albuquerque, NM.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREA: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Adaptive Optics, Atmospheric Turbulence

ATMOSPHERIC OPTICAL TURBULENCE MEASUREMENTS FOR THE U.S. AIR FORCE AIRBORNE LASER PROGRAM

Donald L. Walters, Associate Professor

Department of Physics

Sponsor: U.S. Air Force Space and Missile Command-Phillips Laboratory

OBJECTIVE: To participate in the Atmospheric Optical Working Group for the USAF Airborne Laser Program, and to assess and provide stratospheric, atmospheric, thermal-turbulence measurements.

SUMMARY: A reassessment of the microthermal probes uses by the USAF Airborne Laser Program during the last decade, showed how solar illumination introduced a factor-of-ten error in daytime balloon measurements and how the problem could be eliminated.

PUBLICATION:

Walters, D.L. and Richardson, D.J., "Solar Heating Effects on Balloon-Borne Microthermal Probes for the Airborne Laser Program," Naval Postgraduate School Technical Report, NPS-PH-97-006, August 1997.

CONFERENCE PRESENTATION:

Walters, D.L. and Richardson, D.J., "Modeling and Measurements for the ABL Program," Electro-magnetic and Electro-Optical Conference, Monterey, CA, 2-6 June 1997.

THESIS DIRECTED:

Richardson, D.J., "Solar Heating Effects on Balloon-Borne Microthermal Probes for the Airborne Laser Program," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Airborne Laser Program, Microthermal Probes

MESOSCALE MODELING FOR ATMOSPHERIC TURBULENCE, PHASE I

Donald L. Walters, Associate Professor

Department of Physics

Sponsor: Washington, DC

OBJECTIVE: To assess the state in the art of large mesoscale weather models for computing nowcasts and forecasts of atmospheric optical turbulence for programs of national interest.

SUMMARY: To evaluate and assess large weather models such as the COAMPS and MM5 Mesoscale Weather models to predict atmospheric turbulence and cloud formation. Post-processed model results are being compared with existing atmospheric optical data and to assessing the desirability and direction for further work.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREA: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Mesoscale Models

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