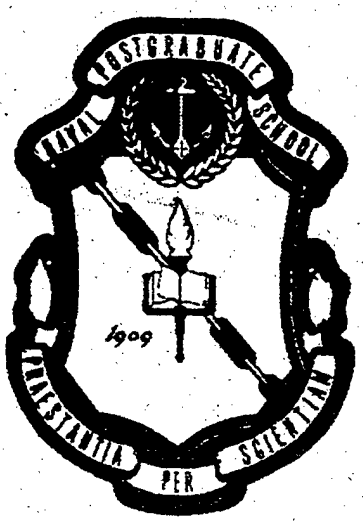
Naval Postgraduate School
Monterey, California 93943-5138

NPS-09-02-014

Summary of

Research

2001



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Naval Postgraduate School

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13. ABSTRACT (Maximum 200 words.)

This report contains project summaries of the research undertaken at the Naval Postgraduate School. A list of recent publications is also included which consists of conference presentations, books, contributions to books, published journal papers, and technical reports. The research was conducted in the areas of National Security Affairs, Computer Science, Defense Analysis, Information Science, Operations Research, Aeronautics and Astronautics, Electrical and Computer Engineering, Mathematics, Mechanical Engineering, Meteorology, Oceanography, Physics and Business and Public Policy. This also includes research by the Space Systems Academic Group, Institute for Information Innovation and Superiority (I2SI), Institute for Defense Systems Engineering and Analysis (IDSEA), The Modeling, Virtual Environments and Simulation (MOVES) Institute, School of Aviation Safety and Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS).

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

RADM David R. Ellison, USN
Superintendent

Richard Elster
Provost

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Associate Provost and
Dean of Research

THE NAVAL POSTGRADUATE SCHOOL MISSION

Enhance the combat effectiveness of the Navy and Marine Corps by conducting and directing advanced education of commissioned officers, and providing such other technical and professional instruction as may be prescribed to meet the needs of the Naval service. In support of the foregoing, and to sustain academic excellence, foster and encourage a program of relevant and meritorious research.

PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four Graduate Schools, Research and Education Institutes, Research Centers and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty during 2001. The summaries are grouped by School and Institute and include an overview, faculty listing, and a compilation of publications/presentations.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department/Group Chair, or the 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 (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.

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

INTRODUCTION

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.

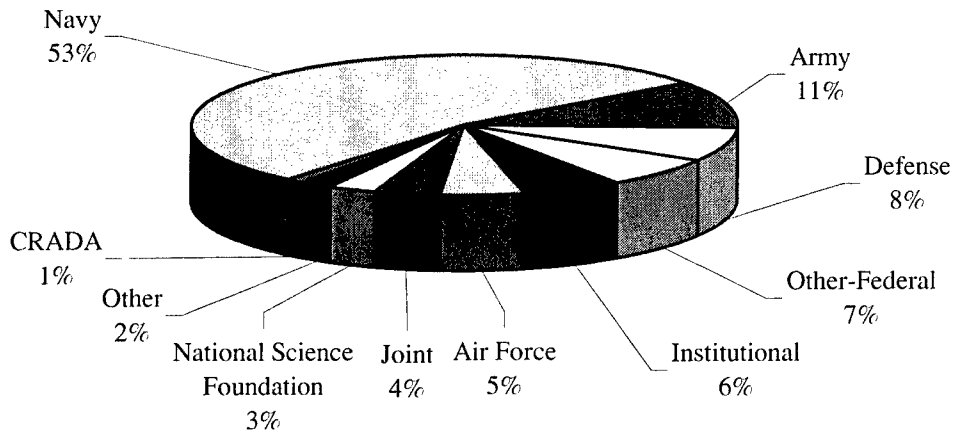

Figure 1. Profile of NPS Research and Sponsored Programs ($52M)

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.

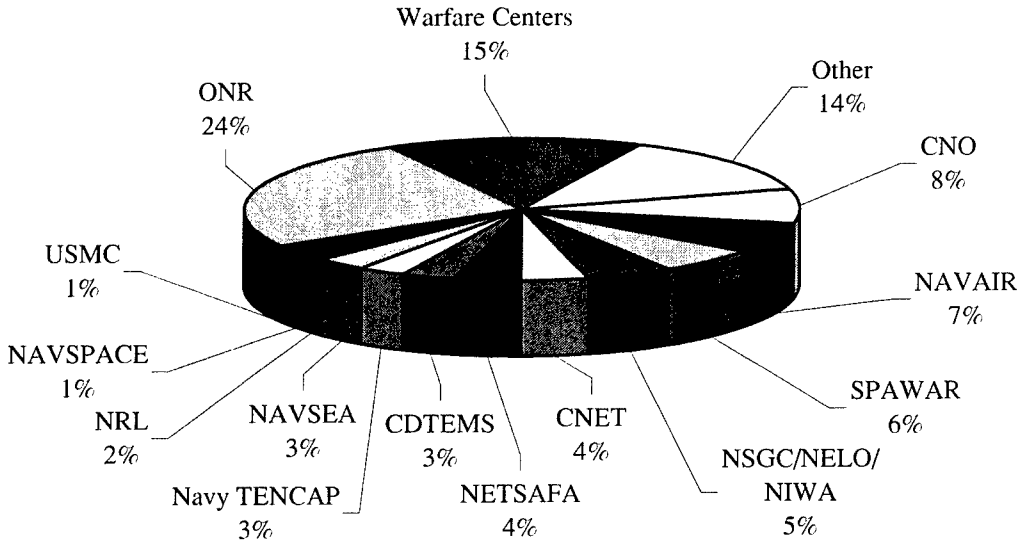

Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs ($29M)

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

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SCHOOL OF INTERNATIONAL GRADUATE STUDIES

PAUL STOCKTON
DEAN

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

JAMES WIRTZ
CHAIR

NATIONAL SECURITY AFFAIRS

OVERVIEW:

The world around continues to evolve at an ever-increasing pace. The tempo of global events demands military officers who can analyze complex issues and think originally. The Department of National Security Affairs (NSA) is uniquely capable of providing an education that encourages these qualities in the officers who study here. The NSA Department bring together distinguished faculty and a highly motivated student body who share a focus on U. S. foreign and defense policies. The Department also tailors its programs to meet sponsor needs through a variety of means, including close ties to Service sponsors, access to classified information, and an intensive program of quality instruction and research.

CURRICULA SERVED:

- Strategic Studies
- Regional Security Studies
- Resource Planning
- Management for International Defense
- Civil-Military Relations and International Security

DEGREE GRANTED:

- Master of Arts in National Security Affairs

RESEARCH THRUSTS:

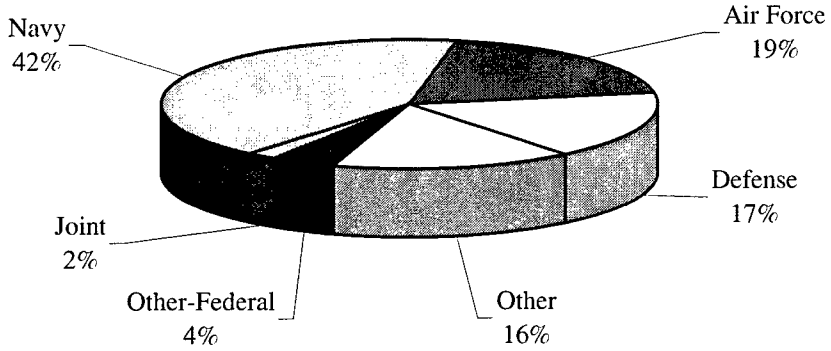
- Strategic Studies
- Joint Intelligence
- Regional Security Studies
- Civil-Military Relations and International Security
- Resource Planning and Management for International Defense (RePMID)

RESEARCH CENTERS:

- Center for Contemporary Conflict

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 National Security Affairs is provided below:



Size of Program: $1357K

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ASYMMETRIC WARFARE IN SOUTH ASIA

Peter R. Lavoy, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: The goal of the project is to conduct a comprehensive analysis of the 1999 India-Pakistan conflict in Kargil.

DoD KEY TECHNOLOGY AREAS: Other (Asymmetric Warfare)

KEYWORDS: India, Pakistan, Weapons of Mass Destruction

DEFENSE GROUP ON PROLIFERATION SEMINAR ON BIO-DEFENSE

Peter R. Lavoy, Assistant Professor
Department of National Security Affairs
Sponsor: Office of the Secretary of Defense

OBJECTIVE: The goal of this research is to organize and host a conference of bio-defense for the U.S. co-chair of the NATO senior Defense Group on Proliferation (DGP) and to provide additional research support as required.

DoD KEY TECHNOLOGY AREAS: Other (Bio-Defense)

KEYWORDS: Biological weapons, Bio-defense, NATO

NATO AND BIO-DEFENSE

Peter R. Lavoy, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: The goal of this project is to host a NATO seminar on Bio-defense in Monterey, CA, 27-29 June 2001.

DoD KEY TECHNOLOGY AREAS: Other (Bio-Defense)

KEYWORDS: Biological Weapons, NATO

REGIONAL SECURITY EDUCATION PROGRAM FOR CARL VINSON BATTLE GROUP

Peter R. Lavoy, Assistant Professor
Department of National Security Affairs
Sponsor: Commander, Pacific Fleet

OBJECTIVE: The goal of this project is to provide educational briefings to the Carl Vincent Battle Group to enhance regional situational awareness of deploying Naval forces.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Regional Security

GLOBAL CIVIL MILITARY RELATIONS

Maria Rasmussen, Associate Professor
Department of National Security Affairs
Sponsor: National Democratic Institute

OBJECTIVE: The Naval Postgraduate School's Center for Civil-Military Relations (NPS-CCMR) and the National Democratic Institute (NDI) have agreed to form the Partnership for Democratic Civil-Military Relations (DCMR). Over a period of three years, the Partnership will launch a series of initiatives intended to facilitate education and dialogue on civil-military relations in new democracies. The objectives of this Partnership are: (i) The Partnership will develop a global information clearinghouse of documents and other civil-military documents. (ii) NPS-CCMR will produce and translate a series of publications combining practical experience with theoretical knowledge. (iii) NPS-CCMR will assist the Universidad Torcuato di Tella in Argentina to develop a one-semester security affairs seminar, which can then be adapted by graduate-level international affairs programs and non-governmental organizations.

DoD KEY TECHNOLOGY AREAS: Other (Civil-Military Relations)

KEYWORDS: Civil-Military Relations, Security Affairs

MILITARY POLICIES OF POST-SOVIET STATES: SOURCES AND CONDUCT

Mikhail Tsypkin, Associate Professor
Department of National Security Affairs
Sponsor: Naval Information Warfare Activity

OBJECTIVE: A study of military policies of post-soviet states will focus on the decision-making mechanisms for formulation and implementation of military policies, impact of revolution in military affairs, and process of military reform.

DoD KEY TECHNOLOGY AREAS: Other (Military Policy)

KEYWORDS: Russia/Ukraine, Military/Security, Doctrine, Decision Making

ARMS CONTROL COMPLIANCE: FUTURE ISSUES

James J. Wirtz, Professor
Department of National Security Affairs
Sponsor: Strategic Systems Program

OBJECTIVE: The purpose of this project is to provide support to the Naval Treaty Implementation Program (SP2025) by responding to a series of research questions related to arms control compliance.

PUBLICATIONS:

Wirtz, J. and Larsen, J., "U.S. Missile Defenses: Three Scenarios and their International Consequences," *National Security Studies Quarterly*, Vol. VII, Issue 4, Autumn 2001.

PRESENTATIONS:

Alibek, K., "Biological Threat and Defense," Navy Treaty Implementation Program Workshop, Naval Postgraduate School, Monterey, CA, 8 February 2001.

Wirtz, J., "Arms Control and Cooperative Security in the 21st Century," International Studies Association Annual Meeting, Chicago, IL, 25 February 2001.

THESIS DIRECTED:

Watson, S., "Nuclear Weapons Accidents and Accidental Nuclear War: Is Pakistan at Risk?" Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Other (Arms Control)

KEYWORDS: Arms Control, WMD, Counterproliferation

ARMS CONTROL IN THE NEW MILLENIUM

James J. Wirtz, Professor
Department of National Security Affairs
Sponsor: U.S. Air Force Headquarters

OBJECTIVE: This project will explore the role of arms control in national security and its contribution to the international stability and U.S. national interest at the dawn of the 21st century. A diverse group of experts on arms control, national defense, proliferation and regional studies will explore the background of arms control theory, its successes and failures during the Cold War, changes to the international security environment in the past fifteen years, and the likelihood of future arms control agreements in various issue areas and geographic regions. Together these analysts will explore contemporary arms control issues and assess the future prospects for arms control policy in U.S. foreign policy and national security strategy.

PUBLICATIONS:

Carr, C., "Africa," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Chevrier, M. "Chemical and Biological Weapons," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Foerster, S., "The International Context *Arms Control,* Cooperative," *Security in a Changed Environment*, Larsen, J., ed., 2001.

Husbands, J., "Conventional Weapons," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Kartchner, K., "A New Offense/Defense Force Mix," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Larsen, J., "Introduction: The Roles and Objectives of Arms Control," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Lavoy, P., "South Asia," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

McCausland, J., "Europe," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

McFate, P, "The Final Frontier: Arms Control in Outer Space," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Nagl, J., "Arms Control in the Year 2025," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

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Rattray, G., "Cyberwar, Information Operations and Arms Control," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

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Schelling, T., "Foreword," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Segell, G., "The Middle East," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Spector, L., "Nuclear Proliferation," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Sim, J., "The Domestic Context," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Waller, F., "Strategic Nuclear Arms Control," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Wheeler, M., "A History of Arms Control: The Experience of the West," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Wirtz, J., "Conclusion: The Future of Arms Control," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

DoD KEY TECHNOLOGY AREAS: Other (Arms Control)

KEYWORDS: Arms Control, Missile Defense, Nuclear Weapons, Nuclear Deterrence, Antiballitic Missile Treaty

JOINT EXPERIMENTATION – RECOMMENDATION OF ADDITIONAL INTEGRATING CONCEPTS

James J. Wirtz, Professor
Department of National Security Affairs
Sponsor: U.S. Joint Forces Command

OBJECTIVE: This project identifies additional integrating concepts related to effects based operations.

DoD KEY TECHNOLOGY AREAS: Other (Joint Operations)

KEYWORDS: Effects Based Operations, Joint Operations

NUCLEAR FORCES IN THE 21ST CENTURY

James J. Wirtz, Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: The project is intended to preserve the body of knowledge about nuclear weapons and strategy generated during the Cold War, adapt and apply this theory and practice to the evolving

international security environment and to supply the next generation of officers and policymakers with the expertise needed to manage the U.S. Nuclear Arsenal well into the 21st century.

DoD KEY TECHNOLOGY AREAS: Other (Arms Control)

KEYWORDS: Nuclear Weapons, Nuclear Defense, Arms Control, Nuclear Stockpile Stewardship

STRATEGY IN THE CONTEMPORARY WORLD

James J. Wirtz, Professor
Department of National Security Affairs
Sponsor: Office of Naval Research

OBJECTIVE: The purpose of this project is to conduct a workshop to identify emerging threats and to update traditional notions about strategy to meet contemporary challenges encountered in using force to achieve political ends.

SUMMARY: Since the end of the Cold War, U.S. analysts and strategists have faced a crisis. On the one hand, they are well versed with the enduring concepts of strategy, intelligence and the procedures and lessons generated by nearly fifty years of Cold War. On the other hand, there is a widespread notion that traditional ways of doing business no longer respond to emerging challenges. Further complicating matters is the fact that the study of strategy and national security issues fell out of fashion during the 1990s, creating an entire generation of junior officers and analysts who have not been exposed to traditional strategic ideas. Events like the Gulf War, Bosnia, Kosovo, Desert Fox, "intelligence surprises" (Indian and Pakistan nuclear testing) and the tragic attacks of 11 September 2001 demonstrate a mastery of the principles of intelligence and strategy are the cornerstone of U.S. foreign and defense policy.

In response to these challenges, James J. Wirtz led a team of highly acclaimed scholars (Professor John Baylis, Professor and Head of the Department of Politics and the Director of the Center for the Study of Conflict at the University of Wales; Professor Eliot Cohen, Director of the Center for Strategic Education in the Paul Nitze School of Advanced International Studies, Johns Hopkins University; and Professor Colin Gray, Director of the Center for Strategic Studies, University of Reading) in a project intended to updating and applying traditional strategic concepts to today's security challenges while creating materials to educate the next generation of officers and civilians in issues of strategy. They assembled an international team of scholars to address:

- Enduring Issues of Strategy
- The Evolution of Joint Warfare
- Twentieth-century Theories and Update
- Contemporary Issues of Grand Strategy

Phase One: With funding supplied by Joint Forces Command (J9) and the Naval Information Warfare Activity, an international conference of strategists, intelligence analysts and policymakers was held at the Naval Postgraduate School, Monterey, California 19-21 September 2000. The conference allowed participants to discuss how traditional strategic concepts to applied to contemporary security challenges. The findings of the conference were supplied to both sponsors in the form of a conference report that was delivered at the close of FY00.

Phase Two: During FY01 participants at the conference further refined their analyses of contemporary strategic and security issues. Chapters were subjected to complete revision in light of comments produced by the editorial team. The editorial process culminated in the fall of 2001 in a manuscript that was submitted to Oxford University Press for publication as a textbook. The final product, *Strategy in the Contemporary World: An Introduction to Strategic Studies* was published in January 2002.

DoD KEY TECHNOLOGY AREAS: Other (Strategic Studies)

KEYWORDS: Naval Strategy, Arms Control, WMD, Joint Strategy

SUPPORT TO NAVAL RESERVE UNIT, ALAMEDA

James J. Wirtz, Professor
Department of National Security Affairs
Sponsor: COMNAVRESREDCOMREG 19

OBJECTIVE: The purpose is to provide a series of lectures to Commander in Chief, Pacific Fleet, Detachment 320. The lectures will cover a broad range of issues of interest to Naval Intelligence.

DoD KEY TECHNOLOGY AREA: Other (Naval Intelligence)

KEYWORDS: National Security Affairs, People's Liberation Army, Asumetric Warfare, National Missile Defense, Media

EUROPE AND INFORMATION WARFARE

David S. Yost, Professor
Department of National Security Affairs
Sponsor: Naval Information Warfare Activity

OBJECTIVE: The objective of this continuing project is to advance understanding of European security policy developments, especially with regard to the information warfare aspects of the "Revolution in Military Affairs." This includes matters such as doctrine, education and training, system development, and technology transfer policy in major NATO European governments, military organizations, and industrial establishments.

SUMMARY: Some theorists contend that a "Revolution in Military Affairs" takes place when new technologies are combined with innovative operational concepts and organizational adaptations that fundamentally change the character and conduct of military operations. This research effort has emphasized the analysis of primary sources from publications in NATO Europe regarding the information warfare aspects of the "Revolution in Military Affairs." A broad definition of "information warfare" has been utilized, in order to encompass means to exploit information systems, to attack those of adversaries, and to protect one's own and those of allies.

PUBLICATION:

Yost, D.S., "The NATO Capabilities Gap and the European Union," *Survival,* Vol. 42, pp. 97-128, Winter 2000-2001.

THESES DIRECTED:

Himes, S., "NATO and the European Union's Emerging Security Role," Masters Thesis, Naval Postgraduate School, March 2001.

Polli, G., "The European Security and Defense Identity: A Challenge for NATO and the United States," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Other (Nuclear Deterrence, Revolution in Military Affairs)

KEYWORDS: France, Europe, Information Warfare, NATO, Nuclear Deterrence, Revolution in Military Affairs

EUROPEAN SECURITY AND NATO NUCLEAR POLICY

David S. Yost, Professor
Department of National Security Affairs
Sponsor: Under Secretary of Defense for Policy and Office of the Secretary of Defense

OBJECTIVE: The objective was to advance understanding of European security policy developments, notably with regard to NATO nuclear weapons policy. This included matters such as nuclear deterrence doctrine in the Alliance and policy debates in major NATO European countries. The issues included the future of nuclear deterrence, conventional deterrence and force planning, missile defense, developments in Russia and elsewhere in the former Soviet Union, the proliferation of weapons of mass destruction, and European security and defense identity.

SUMMARY: Expert observers on both sides of the Atlantic have expressed concern regarding Russian non-strategic nuclear forces (NSNF), including the lack of transparency and the uncertainties about Moscow's implementation of the 1991-1992 commitments. The Russians have to date been unresponsive regarding NATO's proposed confidence and security-building measures (CSBMs) for NSNF.

PUBLICATIONS:

Yost, D.S., "Russia's Non-Strategic Nuclear Forces," *International Affairs*, Vol. 77, pp. 531-551, July 2001.

Yost, D.S., "France's Commitment to Nuclear Deterrence," *Comparative Strategy*, Vol. 20, pp. 251-258, July-September 2001.

Yost, D.S., "France's Commitment to Nuclear Deterrence," *Rationale and Requirements for U.S. Nuclear Forces and Arms Control*, Vol. II: *Foundation Report,* Payne, K., ed., pp. D1-D6, Fairfax, VA: National Institute for Public Policy, 2001.

DoD KEY TECHNOLOGY AREA: Other (Nuclear Deterrence, Revolution in Military Affairs)

KEYWORDS: Strategy, France, Europe, NATO, Nuclear Deterrence, Revolution in Military Affairs

NATIONAL MISSILE DEFENSE AND EUROPEAN SECURITY

David S. Yost, Professor
Department of National Security Affairs
Sponsor: U.S. Air Force Headquarters

OBJECTIVE: The purpose of this project was to advance understanding of NATO European views on U.S. National Missile Defense (NMD) plans, particularly since January 1999. The issues included the future of the 1972 Anti-Ballistic Missile (ABM) Treaty, Theater Missile Defense (TMD), ballistic missile proliferation, deterrence, strategic stability, arms control, and U.S. nuclear commitments to NATO European security.

SUMMARY: As in previous transatlantic debates about missile defense (in 1967-1972 and 1983-1988), the Allies have expressed concern about the implications of U.S. missile defenses for relations with Russia, strategic stability, arms control and nonproliferation, deterrence, and the trans-Atlantic link. Even the old argument that U.S. missile defenses could cause "decoupling" and create "differing zones of security" within the Alliance has been raised. If the ABM Treaty cannot be retained in its current form, Europeans generally declare, they would strongly prefer an amended ABM Treaty or some other U.S.-Russian agreed framework, in the interests of promoting nonproliferation, reassuring public opinion, and maintaining constructive relations with Russia. Despite the strong arguments for U.S.-Russian agreement in jointly terminating the ABM Treaty regime, the Russians appear at present inclined to make the United States bear all the political responsibility of withdrawal from the ABM Treaty. They nonetheless evidently recognize that it would not be in their interests to over-dramatize the implications of such a U.S. decision.

THESIS DIRECTED:

Baze, M.W., "Assessing Russian Reactions to U.S. Missile Defense," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Other (European Security)

KEYWORDS: Russia, Europe, NATO, Strategy, Crisis Management

NATO'S NEW ROLES IN INTERNATIONAL SECURITY

David S. Yost, Professor
Department of National Security Affairs
Sponsor: United States Institute of Peace Fellowship

OBJECTIVE: The objective of this project is to advance understanding of NATO's new roles in international security, particularly with regard to collective security endeavors undertaken on behalf of the international community, such as the peace enforcement efforts underway in Bosnia since late 1995 and in Kosovo since March 1999.

SUMMARY: While the Atlantic Alliance has multiple functions, it originated as, and remains, a group of nations dedicated to collective defense — ensuring protection for the Allies against direct aggression or coercion. Since 1990, however, collective security has become increasingly prominent in the Alliance's words and deeds. The words include NATO's offers, beginning in 1992, to support the United Nations and the Organization for Security and Cooperation in Europe in peacekeeping operations; its commitments since 1994 to the 27 non-NATO nations in the Partnership for Peace; and its declarations that "security is indivisible" throughout what has since the end of the Cold War often been called the Euro-Atlantic area — the vast region consisting of North America, Europe, and the former Soviet Union, including the former Soviet republics in the Caucasus and Central Asia. The deeds encompass the many Partnership for Peace exercises and other activities oriented toward peacekeeping; the efforts to devise Combined Joint Task Forces that could be used for crisis management and peacekeeping by NATO-approved "coalitions of the willing;" and, most significantly, NATO's first military operations involving actual combat — the interventions in the former Yugoslavia that made possible the Dayton accords and the NATO-led implementation and stabilization forces (IFOR and SFOR) in Bosnia and the Kosovo Force (KFOR) in Kosovo.

PUBLICATION:

Yost, D.S., "NATO's Contributions to Conflict Management," *Turbulent Peace: The Challenges of Managing International Conflict,* Crocker, C.A., Hampson, F.O. and Aall, P., eds., Washington, D.C.: United States Institute of Peace Press, pp. 585-602, 2001.

PRESENTATION:

Yost, D.S., "NATO-Russia Relations," NATO: No Action, Talk Only — No More? Conference, U.S. Naval Institute and the Robert R. McCormick Tribune Foundation, Wheaton, IL, 8 March 2001.

THESES DIRECTED:

Inskeep, C.H., "Adaptations in NATO and European Naval Command Organizations Since 1989," Masters Thesis, Naval Postgraduate School, March 2001.

Shupp, B.A., "U.S. Participation in Balkan Peacekeeping: The Rice Proposal," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Other (International Security)

KEYWORDS: Strategy, Europe, NATO, Crisis Management, Collective Security, Peacekeeping

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

2001
Faculty Publications and Presentations

JOURNAL ARTICLES

Wirtz, J. and Larsen, J., "U.S. Missile Defenses: Three Scenarios and their International Consequences," *National Security Studies Quarterly*, Vol. VII, Issue 4, Autumn 2001.

Yost, D.S., "Russia's Non-Strategic Nuclear Forces," *International Affairs*, Vol. 77, pp. 531-551, July 2001.

Yost, D.S., "The NATO Capabilities Gap and the European Union," *Survival,* Vol. 42, pp. 97-128, Winter 2000-2001.

Yost, D.S., "Russia's Non-Strategic Nuclear Forces," *International Affairs*, Vol. 77, pp. 531-551, July 2001.

Yost, D.S., "France's Commitment to Nuclear Deterrence," *Comparative Strategy*, Vol. 20, pp. 251-258, July-September 2001.

CONFERENCE PAPERS

Alibek, K., "Biological Threat and Defense," Navy Treaty Implementation Program Workshop, Naval Postgraduate School, Monterey, CA, 8 February 2001.

Wirtz, J., "Arms Control and Cooperative Security in the 21st Century," International Studies Association Annual Meeting, Chicago, IL, 25 February 2001.

CONFERENCE PRESENTATION

Yost, D.S., "NATO-Russia Relations," NATO: No Action, Talk Only — No More? Conference, U.S. Naval Institute and the Robert R. McCormick Tribune Foundation, Wheaton, IL, 8 March 2001.

CONTRIBUTION TO BOOKS

Lavoy, P., "South Asia," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Wirtz, J., "Conclusion: The Future of Arms Control," *Arms Control, Cooperative Security in a Changed Environment*, Larsen, J., ed., 2001.

Yost, D.S., "France's Commitment to Nuclear Deterrence," *Rationale and Requirements for U.S. Nuclear Forces and Arms Control*, vol. II: *Foundation Report,* Payne, K., ed., pp. D1-D6, Fairfax, VA: National Institute for Public Policy, 2001.

Yost, D.S., "Russia and Arms Control for Non-Strategic Nuclear Forces," *Controlling Non-Strategic Nuclear Weapons: Obstacles and Opportunities,* Larsen, J. and Klingenberger, K., eds., Colorado Springs, CO: U.S. Air Force Institute for National Security Studies, pp. 119-157, 2001.

Yost, D.S., "NATO's Contributions to Conflict Management," *Turbulent Peace: The Challenges of Managing International Conflict,* Crocker, C.A., Hampson, F.O. and Aall, P., eds., Washington, D.C.: United States Institute of Peace Press, pp. 585-602, 2001.

GRADUATE SCHOOL OF OPERATIONAL AND INFORMATION SCIENCES

WAYNE HUGHES
DEAN

DEPARTMENT OF COMPUTER SCIENCE

LCDR CHRIS EAGLE, USN
ACTING CHAIR

COMPUTER SCIENCE

OVERVIEW:

The Department of Computer Science provides graduate training and education in major areas of computer science. Thus, both basic and advanced graduate courses are offered. Course work and research lead to either the degree of Master of Science or Doctor of Philosophy. The requirements to complete either program are rigorous and are comparable to those of other major universities.

CURRICULA SERVED:

- Computer Science
- Software Engineering
- Modeling, Virtual Environments, and Simulation

DEGREES GRANTED:

- Master of Science in Computer Science
- Master of Science in Software Engineering
- Master of Science in Modeling, Virtual Environments, and Simulation
- Doctor of Philosophy in Computer Science
- Doctor of Philosophy in Software Engineering
- Doctor of Philosophy in Modeling, Virtual Environments, and Simulation

RESEARCH THRUSTS AND FACULTY EXPERTISE:

- Software Engineering:
  Professor Luqi, Professor Valdis Berzins, Professor Ted Lewis, Associate Professor Man-Tak Shing, Military Instructor CDR Deborah Kern, and Military Instructor LCDR Chris Eagle
- Databases:
  Associate Professor Thomas Wu, Research Assistant Professor Wolfgang Baer, and Professor Robert McGhee
- Information Security:
  Associate Professor Cynthia Irvine, Lecturer Daniel Warren, and Lecturer Paul Clark
- Artificial Intelligence:
  Professor Robert McGhee, Professor Neil Rowe, and Assistant Professor Chris Darken
- Modeling, Virtual Environments and Simulation (MOVES) Institute/Computer Graphics:
  Professor Michael Zyda, Assistant Professor Rudy Darken, Lecturer Eric Bachmann, Research Professor John Hiles, and Research Professor Michael Capps
- Networks:
  Associate Professor G. M. Lundy, Assistant Professor Geoffrey Xie, and Associate Professor Bret Michael
- Programming Languages:
  Associate Professor Dennis Volpano

RESEARCH FACILITIES:

- Computer Science Academic Laboratory
- Artificial Intelligence and Robotics Laboratory
- Computer Systems and Security Laboratory
- Computer Graphics and Video Laboratory
- Microcomputer Systems Laboratory
- Modeling, Virtual Environments, and Simulation Institute
- Software Engineering Laboratory

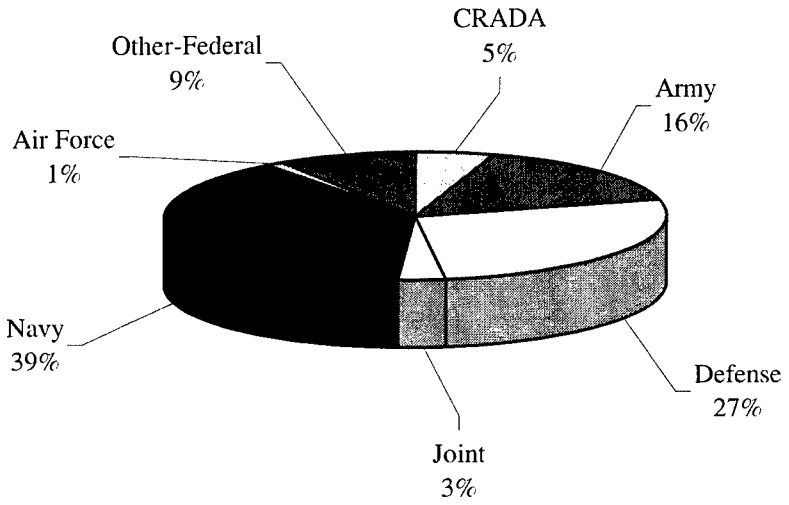
- Visual Database and Interface Laboratory

RESEARCH CENTERS:

- Center for Information Security (INFOSEC) Studies and Research (CISR)
- Software Engineering Center

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 Computer Science is provided below:



Size of Program: $2550K

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BATTLEFIELD DATA PROCESSING COURSE DEVELOPMENT

Wolfgang Baer, Research Assistant Professor
Department of Computer Science
Sponsor: Unfunded

OBJECTIVE: Develop a Course and Research Capability to Support Integration of Virtual Reality and Battlefield Sensing.

SUMMARY: Closing the loop between battlefield sensors and military computer systems in a timely and accurate manner is one of the key requirements for information superiority in 21st century military operations. Future command centers will integrate virtual reality technologies with real-time battlefield sensing systems to support battlefield decisions and data product generation. It is imperative that the future commanders understand the concepts, limits, and capacities of such systems.

The course planned for development focuses on the generation of virtual environment data bases. Emphasis will be on the techniques, data sources, and active research areas which produce realistic representations of geographic areas of military interest.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Computing and Software

KEYWORDS: Virtual Reality, Battlefield Sensing

HIGH RESOLUTION TERRAIN DATA GENERATION SUPPORT

Wolfgang Baer, Research Assistant Professor
Department of Computer Science
Sponsor: U.S. Army TRADOC Analysis Command

OBJECTIVE: Identify and Construct 3D Terrain Feature Models.

SUMMARY: Provides a tool to automatically recognize, measure, and model three-dimensional surface features for addition to one meter resolution terrain database. The database is initialized using standard elevation models (DTED). It then integrates higher resolution ortho-rectified photo imagery and higher accuracy elevation data from a terrain patch of interest. Finally the tool will recognize terrain feature classes such as trees, bushes, rocks, etc. and perform a 3D model fit. The tools also provides for interactive editing of the terrain database in order to allow cosmetic and high fidelity corrections. The tool was delivered in FY 2001 in order to support a 64x64 km database construction at Ft. Hood, TX.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: 3D Terrain, Database

SISO INTRINSIC EARTH SURFACE MATERIAL CLASSIFIER SYSTEM PHASE II

Wolfgang Baer, Research Assistant Professor
Department of Computer Science
Sponsor: U.S. Army TRADOC Analysis Command

OBJECTIVE: Build the infrastructure for the construction of such an earth surface material database at one meter resolution.

SUMMARY: The Simulation Interoperability Standards Organization (SISO) Intrinsic Earth Surface Material Classifier System project will develop the definition of a Standard Surface Material Code (SSMC). To a modeling and simulation program, such a code acts like a pointer to a list of intrinsic earth surface material parameter values that define the physical and radiometric properties of the surface over a broad wavelength range. This information will reside in the Surface Materials Standards list - RESOLVE

(Radiometric Earth Surface Observables for Land Visualization Events), which includes materials based on the global abundance of naturally-occurring, man-made, and non-realistic materials, their significance (e.g. importance) to a user community, and availability of spectral data sources to support extraction of intrinsic surface properties. The standard will also include reversible surface rendering and atmospheric propagation equations to allow a traceable connection between measurement and database content. Tools for extracting intrinsic properties of material from remotely required data are basically nonexistent and the suites of surface rendering tools currently available are limited in scope; in other words, they cover an abbreviated wavelength range or include only a limited set of material types. The goal of our effort is to build the infrastructure for the construction of such an earth surface material database at 1meter resolution.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Standard Surface Material Code, Simulation Interoperability, Standards Organization, SISO

XML TECHNOLOGY ASSESSMENT

Valdis Berzins, Professor
Department of Computer Science
Sponsor: Joint C4ISR Battle Center

OBJECTIVE: The Joint C4ISR Battle Center (JBC) needs an assessment of technical issues related to the use of XML to achieve data interoperability in military systems. An XML schema should accommodate controlled change to enable incremental approaches to implementation that add one system at a time. If changes are done according to the least effort for each individual data interchange connection between legacy systems, eventually become a severe maintenance problem. The NPS Software Engineering Group proposes to evaluate and assess different methods for alleviating this problem.

SUMMARY: The use of XML has been investigated for achieving data interoperability between DoD legacy systems from several points of view: methods for integrating XML schemas covering data interchange between pairs of systems, methods for using XML to transfer data between heterogeneous databases, and XML for data interchange between real-rime systems. The capabilities of commercial tools have been assessed related to XML and XML interfaces to the commercial database systems used in the systems of interest to JBC. Methods have also been assessed for translating between different XML representations of the same real-world data, corresponding to the different views of that data as modeled in different legacy systems.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: XML, Legacy Systems, Software Engineering

MV-22 CREW TRAINING FOR DEPLOYED EXPEDITIONARY FORCES: MARINE CORPS AIR TO GROUND OPERATIONS

Rudolph P. Darken, Assistant Professor
CDR (sel) Joseph Sullivan, USN, Military Instructor
Sponsor: Office of Naval Research

OBJECTIVE: To design and construct a deployable training system for the Navy and Marine Corps helicopter and rotocraft aviation communities focusing on team tasks, specifically air to ground operations.

SUMMARY: This project involves the development of a deployable training device for the MV-22 platform and helicopters capable of performing air to ground operations. The trainer will be deployable, interoperable with other trainers, cost effective, reconfigurable, and the investigators will also conduct training assessment evaluation to assure positive training transfer. A rudimentary task analysis has been

completed which will need to be redone more thoroughly next year. A fully implemented prototype system that uses a bluescreen (Chromakey) solution for mixed modes of display is available.

PUBLICATIONS:

Darken, R., Kempster, K. and Peterson, B., "Effects of Streaming Video Quality of Service on Spatial Comprehension in a Reconnaissance Task," *Proceedings of I/ITSEC*, Orlando, FL.

Peterson, B., Boswell, J. and Darken, R., "Collaborative Navigation in Real and Virtual Environments," *Proceedings of I/ITSEC*, Orlando, FL.

THESIS DIRECTED:

Boswell, J., "User-Centered Iterative Design of a Collaborative Virtual Environment," Masters Thesis, Naval Postgraduate School, March 2001.

Hennings, C., "Designing Realistic Human Behavior into Multi-Agent Systems," Masters Thesis, Naval Postgraduate School, September 2001.

Mert, E. and Jilson, E., "Modeling Conventional Land Combat in a Multi-Agent System Using Generalization of the Different Combat Entities and Combat Operations," Masters Thesis, Naval Postgraduate School, September 2001.

Norlander, K., "Emergent Leadership on Collaborative Tasks in Distributed Virtual Environments," Masters Thesis, Naval Postgraduate School, September 2001.

Unguder, E., "The Effects of Natural Locomotion on Maneuvering Task Performance in Virtual and Real Environments," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Human Systems Interface, Modeling and Simulation

KEYWORDS: Training, Virtual Environment

AN EXECUTIVE LEVEL INFORMATION TECHNOLOGY EXPLOIT DEMONSTRATION

Cynthia E. Irvine, Associate Professor
MAJ Michael VanPutte, USA
Department of Computer Science
Richard Harkins, Lecturer
Department of Physics
Sponsors: Headquarters, Department of the Army

OBJECTIVE: This proposal is in the development of an executive level demonstration of information security vulnerabilities and exploits. The purpose is to open the eyes of non-technical DoD leaders to the risks that are inherent in current information technology systems, so they can understand and make policy.

SUMMARY: This report is interim and describes and ongoing effort. The purpose of this effort is to develop an executive level stand-alone demonstration of current computer security threats and exploits. The demonstration will consist of a "worst case" scenario presentation of various (unclassified) cyber threats and vulnerabilities, illustrating the skills required to exploit the vulnerabilities and, where available, courses of action to reduce those threats. The intent is to present to non-technical military and DoD leaders an executive demonstration of current Information Assurance threats, risks, and countermeasures. The demonstration will include not only trivial attacks that can be mounted by "ankle-biters" or that result from careless or inadequate procedural measures on the part of authorized users, but will also illustrate attacks that are preferred by state-sponsored or other well-funded professionals. Thus, the demonstration will

provide decision makers with the information that they need to *understand* and make high level policy in the area of computer and network security and the risks associated with information technology.

An unclassified "sand box" laboratory is being developed to produce the highest level of realism and accuracy in the demonstration. Areas include network infiltration and exploitation, wireless infrastructure threats, malware threats, Trojan Horses, trap doors, and PDA threats. Each of the attack or exploitation areas is being explored for vulnerabilities and attack scenarios have been hypothesized. This is followed by test or implementation. When possible, methods to mitigate vulnerabilities are identified. Both the attacks and a discussion of techniques to thwart them are being incorporated into the demonstration.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Information Assurance, Vulnerability Exploitation, Threats

HIGH ASSURANCE MULTILEVEL COMPUTING ENVIRONMENT, PHASE II

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Navy Engineering Logistics Office

OBJECTIVE: This research is to continue work in support of a high assurance distributed multilevel computing environment, building on recent work accomplished on the Naval Postgraduate School High assurance label processing mail service prototype undertaken during Phase I. Areas of study include applicability to collaborative environments, extension of label processing, trusted path extensions, and supporting policy adaptations.

SUMMARY: The prototype High Assurance system functionality was extended in the following ways: (1) Modifications to the Trusted Path Server, Secure Session Server, 'sendmail' daemon and HTTP server on a high assurance platform were finalized, (2) An initial Java prototype of a generic client TCB Extension was produced; high assurance server functionality was ported to the Linux operating system base. This work permits a multilevel version of Ethernet support as well as dynamic instantiation of protocol services in conformance with client security attributes. (4) A similar port to the Open BSD operating system was started. (5) The design of a PDA-based trusted path mechanism to be used in the context of a contemporary server (e.g. Linux or OpenBSD) was begun. The client trusted path device is envisioned to be a hand-held component juxtaposed between the client workstation and the server.

Preliminary sketches of an architecture for self-protecting data were prepared. An option in this design is to use a specialized reader device. The use of Intelink/CAPCO metadata tags to support visual labeling of paragraph markings, as well as access control to XML/HTML documents was investigated.An initial study of security vulnerabilities associated with the use of popular applications on the connectionless User Datagram Protocol (UDP) was conducted. This included examination of several Voice over IP (VoIP) suites. It was found that for a number of the most popular products ensuring performance was paramount and that security was turned off when VoIP was turned on.

Based upon the need to provide standard commercial-grade productivity applications as the general purpose user interface to high-assurance data processing environments is compelling in the context of "trusted" systems, the problem of integrity in architectures comprised of both traditional trusted components and less trusted components was explored. Some of these systems were characterized as a class of architecture. This lead to the development of a general integrity property that systems can only be trusted to manage modifiable data whose integrity is at or below that of their interface components. The analysis led the effect that in terms of integrity high-assurance systems cannot be composed of a combination of high assurance policy-enforcement components and low assurance commercial interface/application components. Another effect is that this type of these hybrid-security systems are only applicable to processing environments where the integrity of data is consistent with that of low-assurance software.

PUBLICATIONS:

Irvine, C.E., Levin, T., Wilson, J.D., Shifflett, D. and Pereira, B., "A Case Study in Security Requirements Engineering for a High Assurance System," *Proceedings of the 1st Symposium on Requirements Engineering for Information Security*, Purdue University, Indianapolis, IN, 5-6 March 2001.

Irvine, C.E. and Levin, T., "Data Integrity Limitations in Highly Secure Systems," *Proceedings of the International Systems Security Engineering Conference*, February 2001.

Irvine, C.E. and Levin, T., "A Cautionary Note Regarding the Data Integrity Capacity of Certain Secure Systems," Fourth International IFIP Working Conference on Integrity and Internal Control in Information Systems, Brussels, Belgium, 15-16 November 2001.

THESIS DIRECTED:

Glover, M., "Integrating a Trusted Computing Base Extension Server and Secure Session Server into the Linux Operating System," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information Assurance, Multilevel Security, High Assurance

MSHN: MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: Research and design effort directed at solving the fundamental problems associated with and creating a distributed metacomputer.

SUMMARY: Phase I of the MSHN Project was completed in 2000. This report provides s a summary of project research and additional publications emerging from the project.

The accomplishments of the project include a peer-to-peer architecture composed of the following components: client library, scheduling advisor, resource requirements database, resource status server, MSHN daemon, application emulator. The architecture supports the execution of many different client applications, both new and previously unencountered.

Mapping algorithm research supported the MSHN scheduler and resulted in the development of a "toolbox" of mapping techniques from which the scheduler can select the most appropriate algorithm for a given heterogeneous computing and application environment. A unified mapping framework was developed addressed two mapping problems: mapping with advance reservation and data replication, and mapping with resource co-allocation requirements.

MSHN produced a resource model that allows the system to make mapping decisions. Monitoring is needed to ensure that model represents the resources available. Strategies were developed to permit monitoring to be performed at each client. A number of techniques and tools were explored to permit the monitoring and modeling of communications resources.

The research explored the problem of distributed communications in an environment requiring transfers of large quantities of data. A uniform framework for developing communication schedules for collective communication patterns was introduced. The schedules were adapted at run-time, based on network performance information.

Performance metrics were developed so that the success of MSHN as a resource management system could be measured. A multidimensional performance measure was developed that included: priorities, task and data versions, deadlines, situational modes, security, and other dependencies.

Security was an integral part of the MSHN project. A multi-domain cryptographically enforced security architecture was developed that provided authentication and confidentiality for MSHN components. The notion of Quality of Security Service was introduced and developed as part of the project.

PUBLICATIONS:

Kim, J.K., Kidd, T., Siegel, H.J., Irvine, C., Levin, T., Hensgen, D.A., St. John, D., Prasanna, V.K., Freund, R.F. and Porter, N.W., "Collective Value QoS: A Performance Measure Framework for Distributed Heterogeneous Networks," *Proceedings of the 15th International Parallel and Distributed Processing Symposium*, pp. 810–823, 2001.

THESIS DIRECTED:

Drake, T., "Design and Implementation of a Real-Time Distributed System Emulator," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Heterogeneous, Distributed Computing, Data Staging, Metacomputing

MSHN: SECURITY ARCHITECTURE AND QUALITY OF SECURITY SERVICE FOR RESOURCE MANAGEMENT SYSTEMS

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Defense Advanced Projects Research Agency

OBJECTIVE: This is an extension of ongoing work in the area of quality of security service (QoSS) and security architectures for resource management systems (RMS). The theory of QoSS was broadened and the QoSS framework extended through experimentation with mechanisms to provide QoSS in the context of a RMS. Security requirements of RMS applications will be identified to further refine needed architectural and QoSS support.

SUMMARY: A method for articulating network security functional requirements, and for measuring their fulfillment has been developed. Using this method, security in a quality of service framework (QoSS) is discussed in terms of variant security mechanisms and dynamic security policies. It was also shown how QoSS can be represented in a network scheduler benefit function.

This research continued to address the problem of how users and administrators can easily interact with the wide range of security resources and mechanisms. A method for translation of a simplified user abstraction of security to detailed underlying mechanisms was further refined.

An approach for representing the level of resources consumed by jobs under the control of a resource management system was extended. This work continued to show how this measurement of resource usage can be combined with a notion of user preferences to reflect a restrictive resource-usage policy for network management.

Based upon a preliminary security service taxonomy defined to provide the resource management system with potential resource utilization costs, a demonstration of our framework was developed for defining the costs of various network services. Using IPSec in OpenBSD, a demonstration of Quality of Security Service was constructed. Based upon environmental conditions, security associations between peer systems are selected according to a predefined policy. Environmental conditions relating to the network mode and user security requirements may change. When this occurs, security associations are broken down and re-established.

PUBLICATIONS:

Irvine, C., Levin, T. and Sypropoulou, E., "Security as a Dimension of Quality of Service in Active Service Environments," *Proceedings of the International Workshop on Active Middleware Services*, San Francisco, CA, 6 August 2001.

THESIS DIRECTED:

Agar, C., "Dynamic Parameterization of IPSec," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Security, Information Assurance

NAVY INFORMATION WARFARE/INFORMATION SECURITY/INFORMATION ASSURANCE SUPPORT PLAN FOR NPS CISR

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Chief of Naval Operations (N643)

OBJECTIVE: The aim of this research is to provide support for the Naval Postgraduate School Center for INFOSEC Studies and Research (NPS CISR) in an integrated approach to INFOSEC research and education. The program will focus on network and platform security problems of importance to DoN and DoD.

SUMMARY: Several ongoing projects intended to support the emerging DoD public key infrastructure (PKI) were started. These included an examination of the feasibility of the use of the PKI in tactical situations. Another study involved configuration management issues for deployed PKI components. A third research effort is explored metrics for the service level agreement (SLA) for operational services relating to the PKI that are required for the Navy Marine Corps Internet.

PKI training within the DoD was examined and found unable to provide all of its users with an adequate level of general understanding of the system as a whole, or of the implications and ramifications that their individual actions may have upon the system. A decentralized, segmented, and inconsistent approach to PKI training will result in a lack of trust within the PKI. The initial requirements and design for a coherent web-based training framework for the DoD PKI were developed. A prototype was developed for further testing and evaluation.

Human factors in the perceived and actual level of security awareness was the topic of another investigation. A survey was developed to assess security awareness within the U.S. Coast Guard. this was followed by analysis and a plan to improve security awareness was recommended.

Highly trustworthy user interfaces for an open source operating system constituted another area within the scope of this research. The objective was to identify all of the mechanisms within the keyboard interface that represent trap doors in the open source system and to modify the design of the input subsystem so that a trustworthy secure attention key was possible. Additionally, this work resulted in the development of a state representation of the interface that could be used for subsequent design of a trusted path interface.

Using the Situational Influence Assessment Module (SIAM), classical risk analysis was expanded to increase visualization of choices that impact the security of a system, in this case a firewall. By providing a comparative analysis of system attributes communications between decision makers and technicians is encouraged. This increased understanding of the impact of investment choices has the potential to increase the security posture of existing systems.

The implications of the use of human microchip implants to permit radio frequency identification of personnel were investigated. This work included a survey of current technologies for enhanced user identification, focusing on human implant approaches and a summary of security, privacy, social and ethical issues that may arise from the use of these technologies in the U.S. Navy. It was found that the collateral social issues are complex and far-reaching. Potentially intractable technical, morale and legal issues must be avoided by the U.S. Navy. The results of this exploratory work show: 1) technology must be examined in the context of its social impact, and 2) there is a valid need for future research and analysis of human microchip implants.

Research into platform architectures and their ability to support secure systems involved examination of the Intel IA-64 platform. Hardware protection mechanisms were examined and included mechanisms

for: privilege levels, access rights, region identifiers and protection key registers. It was found that proper use of the TLB-based hardware protection features permits some protection in the IA-64 architecture.

In addition, the Intel IA-64 architecture was analyzed for virtualizability with respect to the three classical virtual machine monitor definitions and their hardware requirements. Although the IA-64 architecture meets the three hardware requirements, the IA-64 instruction set contains 18 sensitive unprivileged instructions. These instructions prevent the IA-64 architecture from being used for a Type I VMM.

A study of Windows 2000 configuration for NPS was conducted with the objective of describing a secure configuration as well as the rationale for its settings. This work resulted in: (1) brief overview of the Microsoft Windows 2000 security architecture, (2) a description of the Windows 2000 Security Configuration Tool Kit and how to configure security settings, (3) a discussion on security policy and how it effects security configurations, (4) recommendations on how to translate the Naval Postgraduate School's Security Policy into Windows 2000 security settings, and (5) recommendations on a pre-configured, security template for all students attending NPS.

PUBLICATIONS:

Irvine, C.E. and Levin, T., "Teaching Security Engineering Principles," in Armstrong, H. and Yngstrom, L., eds., *IFIP TC11 WG 11.8 Second World Conference on Information Security Education*, Perth, Australia: Edith Cowan University, pp. 113-127, July 2001.

Clark, P., "Supporting the Education of Information Assurance with a Laboratory Environment," *Proceedings of the 5th National Colloquium for Information Systems Security Education*, May 2001.

THESIS DIRECTED:

Brock, J., "Supporting the Secure Halting of User Sessions and Processes in the Unix Operating System," Masters Thesis, Naval Postgraduate School, June 2001.

Brodhun, C.P., "Prioritization of Information Assurance (IA) Technology in a Resource Constrained Environment," Masters Thesis, Naval Postgraduate School, September 2001.

Gumke, R., "Navy Marine Corp Internet Information Assurance Operational Services Performance Measures," Masters Thesis, Naval Postgraduate School, June 2001.

Jubert, L., "Implications of User Identification Devices (UIDs) for the United States Navy," Masters Thesis, Naval Postgraduate School, September 2001.

Karadeniz, K, "Analysis of Intel IA-64 Processor Support for a Secure Virtual Machine Monitor," Masters Thesis, Naval Postgraduate School, March 2001.

McGovern, S., "Information Security Requirements for a Coalition Wide Area Network," Masters Thesis, Naval Postgraduate School, June 2001.

McKinley, D., "Implementing the Naval Postgraduate School's Security Policy Using Windows 2000," Masters Thesis, Naval Postgraduate School, September 2001.

Stocks, A., "Requirements for the Deployment of Public Key Infrastructure (PKI) in the USMC Tactical Environment," Masters Thesis, Naval Postgraduate School, June 2001.

Unlamis, B., "Analysis of the Intel IA-64 Processor Support for Secure Systems," Masters Thesis, Naval Postgraduate School, March 2001.

Whalen, T., "Human Factors in Coast Guard Computer Security -- An Analysis of Current Awareness and Potential Techniques to Improve Security Program Viability," Masters Thesis, Naval Postgraduate School, June 2001.

Zembia, M., "A Training Framework for the Department of Defense Public Key Infrastructure," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information System Security, INFOSEC, Information Assurance, Network Security

NPS CISR SCHOLARSHIP FOR SERVICE: SCHOLARSHIP TRACK

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: The objective of the proposed work is to provide Master's level education in the science and practice of Information Assurance to selected students who would subsequently be available and obligated to perform two years of Federal service in the same field.

SUMMARY: Students with undergraduate computer science degrees will be placed into a specially designed two-year computer security track within the Center for INFOSEC Studies and Research (CISR) at the Naval Postgraduate School. This four-year Scholarship for Service program will initiate a stream of ten students per year for the first three years, graduating the final set of ten students at the end of the fourth year.

Through courses involving extensive laboratory exercises and projects, student will learn how to design, build, configure, and manage systems and networks securely. During their two years of study, the program will provide students with a firm grounding in the foundations of computer science and the concepts and techniques for understanding modern information assurance.

The program is intended to have a significant effect toward filling the current personnel gap in Information Assurance for the national information infrastructure.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information Assurance, Critical Infrastructure Protection

PUBLIC KEY INFRASTRUCTURE (PKI) LABORATORY EQUIPMENT - FY01
PUBLIC KEY INFRASTRUCTURE (PKI) LABORATORY SUPPORT AND EXTENSION

Cynthia E. Irvine, Associate Professor
J.D. Fulp, Lecturer
Department of Computer Science
Sponsors: National Security Agency and Office of the Secretary of Defense

OBJECTIVE: (1) This proposal is for Laboratory equipment in support of the Public Key Infrastructure (PKI) Laboratory operated by NPS CISR. This laboratory will support information Assurance (IA) education and a forthcoming cyber defense exercise. (2) This proposal is for laboratory equipment in support of the Public Key Infrastructure (PKI) Laboratory operated by NPS CISR. This laboratory will support Information Assurance (IA) education and a forthcoming Cyber Defense Exercise.

SUMMARY: The NPS CISR PKI Lab provides students and research faculty with the necessary system resources to study implementation and security issues relating to PKI. Issues include, but are not limited to: 1) Implementation of the various PKI functional components (e.g., Certificate Authority/Server, Registration Authority/Server, Certificate Revocation List, Key Archival and Recovery, etc.), 2) Interoperability among DoD users, 3) Interoperability between DoD and non-DoD users, 4) Public Key enabling of applications, and 5) Certificate Trust Hierarchies and Relationships.

Equipment for the PKI lab was initially provided in February of 2001 under the auspices of the DoD PKI Program Management Office (PMO). An equipment upgrade was funded by the PMO in September of

2001. To provide a more interesting and dynamic venue for the introduction of PKI to DoD Service component student officers, the PMO and Service School representatives embarked on a plan to wrap the usage of PKI inside a student run IA exercise – the "Cyber-Defense Exercise" (CDE).

The first CDE was conducted in April of 2001, though the compressed procurement-to-implementation timeframe did not allow integration of PKI into the exercise. NPS was judged the un-official winner of the 2001 CDE based upon the judgment of IW professionals from the NSA, USAF, and US Army (collectively the "Red Team") who conducted a week long barrage of offensive exploits against each school's network. The "un-official" win status is due to NPS' unique status as the only postgraduate competitor in the exercise.

Planning for the 2002 CDE has been ongoing and will culminate in the actual attack/defend phase during the week of 22 April. PKI will be utilized for the signing and encrypting of daily situation reports from each school to White Team (referee) participants at Carnegie Mellon University. The situation reports will document the status of each school's network following each day's eight-hour attack period. The reports will also list any offensive intrusion exploits that were logged or otherwise identified by the defending team. The winner will be chosen based upon two criteria: 1) The accuracy and specificity of the situation reports, and 2) The relative resistance to, and ability to recover from, Red Team exploits.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Network Security, Public Key Infrastructure (PKI), Authentication

SECURITY-ENHANCED WINDOWS CE

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsors: Microsoft Corporation

OBJECTIVE: The objective of the Secure Windows CE project is to examine the data protection and self protection features of the Windows CE Operating System and to develop structural modifications and enhancements to the Windows CE operating system that would increase its level of self protection. As a result users would have greater confidence of the ability of Windows CE devices to withstand attempts to penetrate or subvert them, and consequently to have greater confidence in the ability of Windows CE to protect data entrusted to it.

SUMMARY: In the absence of source code, preliminary studies of the Windows CE system in the form of black box analysis. Documents from the open literature as well as existing systems were used as the basis for two analyses.

In the context of general security redesign of operating systems the applicability of such redesign to the Windows CE operating system was explored. The operating system was critically examined for externally visible security weaknesses, especially in the Input/Output subsystem area. Recommendations were made for improving the self-protection of Windows CE.

Threads and processes in WinCE, as well as authentication, and public key infrastructure (PKI) support were examined. It was found that *Talisker*, the next generation of WinCE, supports Kerberos an authentication protocol, and it also supports PKI (a key management system) components. Using selected applications and configuration management security on a Talisker platform can be significantly enhanced beyond that usually supplied in "out of the box" systems.

THESIS DIRECTED:

Burns, T., "Analyzing Threads and Processes in Windows CE," Masters Thesis, Naval Postgraduate School, September 2001.

Pereira, B., "Analyzing Input/Output Security in Windows CE," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Information Assurance)

KEYWORDS: Computer Security, Information System Security, INFOSEC, Information Assurance, Network Security

SIM SECURITY

Cynthia E. Irvine, Associate Professor
Department of Computer Science
Sponsor: Chief of Naval Education and Training

OBJECTIVE: The purpose of this research is to create a distance learning lab to support hands-on learning, working with or without distance learning modules, focusing on the subject of information assurance (IA).

SUMMARY: This project is ongoing. The following summarizes project objectives. The purpose of this effort is to create a distance learning lab to support hands-on learning, working with or without distance learning modules, focusing on the subject of information assurance (IA).
The lab will be based on existing course material that meets NSTISSC Standard 4011 as well as all or part of the other NSITISSC Standards pertinent to Information Assurance.

SimSecurity will package an Information Assurance laboratory in the form of an interactive computer game in which players may perform various roles involved in IA: manager, security administrator, attacker, etc. Through the use of agent-based software techniques, the laboratory will adapt to the decision or omissions of students, providing them with a customized learning experience. The agent-based software underlying this laboratory facilitates extensions as new threats and countermeasures in the real world IA landscape evolve.

The laboratory will support both IA Training and IA Education. It can be used in an ad hoc fashion to teach users IA concepts and vocabulary. When used as a self-contained laboratory it provides an introduction and tutorial providing a basic introduction to IA concepts and their application. When combined with a course, students navigate through the IA lab in a systematic program. When used in conjunction with learning modules and courses, such as those developed by the Center for INFOSEC Studies and Research at the Naval Postgraduate School, students progress through a rigorous sequence of labs and lectures to a NSTISSC-based certification and/or course credit from NPS.

A model of Information Assurance and a series of scenarios for the simulation have been developed. Additional details of the model and scenarios will be developed. Initial artwork has been created to provide backdrops for several scenarios.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Education, Information Assurance, Simulation

ASSESSMENT OF DEFENSE MODELING AND SIMULATION OFFICE (DMSO) CONCEPTUAL MODELS OF THE MISSION SPACE

Luqi, Professor
Department of Computer Science
Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: The objectives of this project are to provide a quantitative assessment of the value-added due to the DMSO data engineering and Conceptual Models of the Mission Space (CMMS) products and to provide useful measures of the health and the status of work in progress. Ongoing NPS faculty and graduate students' efforts on software requirements analysis and risk reduction were leveraged to address these objectives.

SUMMARY: The assessment addressed the value added by DMSO data engineering concepts and tools, as well as metrics to support cost estimation, scheduled planning, status of work in progress, conceptual

model complexity, and software defect evaluation. In FY01, we focused our assessment efforts in the following areas: (A) effectiveness of software risk assessment models, (B) enhancement to the functional description of the mission space resource center, (C) the use of XML and Wrapper-based translators for heterogeneous DoD databases, and (D) metrics for systematically evaluating and selecting automated testing tools.

A. Quantitative risk assessment for software development: Investigation continued on formal risk assessment models for the evolutionary software process and their application to DMSO projects. The methods and tools were analyzed and improved to assess the risk and the duration of software projects automatically, based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. These metrics eliminate the subjectivity issue characteristic of previous research. Any decision-maker will arrive at the same estimates, independent of his or her expertise. The approach enables a project manager to evaluate the probability of project success very early in the life cycle. For more than twenty years the estimation standards (COCOMO 81, COCOMO II, Putnam) have been characterized by the common limitation that the requirements should be frozen in order to make estimations. Our models remove this limitation, facing the reality that requirements are inherently variable. The effectiveness of the models was validated by comparing the results of the models against data collected from 16 simulated projects and 3 large, real projects.

1. Sixteen Simulated Projects: The simulations showed that the three risk factors observed during the causal analysis (efficiency, requirements volatility, and complexity) have compound effects over the three parameters of the Weibull distribution. The results of the models were illustrated against 16 simulated projects. Each model derives an increasing degree of accuracy based on: metrics from the three risk factors, Weibull cumulative density function, and the derivation of the time.
   - Models 1-2: Model 1 can be used when the requirements volatility is small. Model 2 considers the three factors (EF, RV, and CX), but neglects the combined effect of EF and RV.
   - Model 3: Model 3, illustrated in Figure 2, considers the three factors as well as the combined effects of EF and RV. The analysis of variance shows that the samples obtained from the simulations and the samples obtained from the estimates using Model 1, 2 or 3 cannot be statistically differentiated.

     Another interesting result is that the errors remain in the range of (15% for all of the scenarios. This result is interesting if we compare it with the results of COCOMO ((20% in the best cases). Barry Boehm in reference to the validation of COCOMO said, "In terms of our criterion of being able to estimate within 20% of projects actuals, Basic COCOMO accomplishes this in only 25% of the time, Intermediate COCOMO 68% of the time, and Detailed COCOMO 70% of the time."
   - Model 4: Model 4, can be used for any range of complexity and requirements volatility, and considers the three factors, their combined effects, and the following a priori assumptions:
     * A project with 0 LGC will take 0 days
     * (, (, and (> 0
     * If RV increases the p(x<=t) decreases
     * If CX increases then p(x<=t) decreases
     * If EF increases then p(x<=t) increases

     The scatter plot derived compares the simulated times versus the estimated times. Most of the errors are overestimations and the duration of the project has no effect over the percentage of error. Model 4 is conservative. The maximum overestimation error was less than 16% and the maximum underestimation was less than 4%.

     Model 4 gives a good estimation for projects between 4,000 and 20,000 LGC (128 and 640 KLOC of Ada). The estimation seems to be too optimistic for projects smaller than 1000 LGC but it is quite good for larger projects.
2. Uruguayan Navy Project: Model 4 was on a war-gaming simulator with 75,240 lines of code. The software was made up of 1836 LGC and was developed in 1.5 years by the Uruguayan Navy. Model 4 predicts 17 months instead of 18 months, the actual development time.
3. U.S. DoD Project A: This project used an Evolutionary Spiral lifecycle model. It used Object-Oriented methodology and was composed of five computer software configuration items written in Ada. It was real-time embedded, and used Rational Rose as a Computer Aided Software

Engineering tool with the developer operating at SEI level 3. In addition, software metrics from three builds over a period of three years had been kept.

Model 4 was used to calculate the probability of completion curve for the project. For consistency, we used working days, defined as 22 days per month, the same as used in the original Nogueira model.

The model predicted that the minimum time, in days, necessary to have a probability of completion of 100% is approximately 260 working days. When compared to the actual time it took, which was 336 working days, the model predicted completion sooner. The model predicted 76 working days less, or a 22.6% delta: (1 - (260 / 336)) (100) = 22.6%.

At this point, with 22.6% variability, we decided to investigate and see what the original estimated completion date was from project records. The original estimation was 200 working days, with the project schedule slipping 136 working days for build 3. The developer missed the original completion estimation by 40.5%: (1- (200 / 336)) (100) = 40.5%.

The Nogueira model missed the developer's original estimate by 23.1%: (1-(200 / 260)) (100) = 23.1%. This data point leaves us with an inconclusive position as to the validation of the model against the first project. It appears that there is a difference when using projects with real data versus simulated project data, reflecting what the real world is - unpredictable.

4. U.S. DoD Project B: This project originally used an incremental build lifecycle model and not an evolutionary model. It originally used Functional Decomposition methodology and was composed of six Computer Software Configuration Items. Written in ADA and assembly language, it was real-time embedded. It did use upper CASE tools, like Requirements Traceability Matrix (RTM), however did not use lower CASE tools such as Rational Rose. The development effort initially was performed in an ad-hoc manner with little software process involved and had experienced extreme volatility and poor metrics early in its development. However, due to a major restructure and overhaul of the project, and a shift of focus to institutionalizing software processes, (SEI CMM level 3 certification), the project migrated to ADA, and began using a modified Incremental Build lifecycle model. In addition, suitable software metrics from two recent builds were available. We used Dr. Nogueira's Model 4 to calculate the probability of completion curve for Build 2 using; BR=2.59, DR=3.04, RV=5.63, O=2544, D=4010, T=1003. The model predicted Impossible.

   Actual time for build 2 took from 4/24/00 until 7/10/00 or 68 working days at 22 working days a month. We believe this inconsistency is due primarily to the calculation for the LGC count being based on all six Computer Software Configuration Items (CSCI). Core functionality on three CSCIs; CSCI-A, CSCI-B, and CSCI-C had been previously developed and validated. However, the builds during this period, involved addition of functionality to the following CSCIs: CSCI-D, CSCI-E, and CSCI-F. That is, build 2 was modifying only a portion of the total software system code, but the LGC data gives a view of all six CSCIs combined.

   The available data was not broken down into separate CSCIs, nor did it, post-mortem, identify the code that was being worked in a previous software release. We cannot fault the developer for not collecting metrics for research concepts that they are not aware of, nor do we believe that this type of data collection is a requirement of CMM level 3.

   A finding of this research is the need to adjust the CX when applying the Nogueira model to evolved projects that are developing or enhancing only a portion of their CSCIs.

   As previously stated, this project did not utilize a lower case tool such as Rational Rose. We believe use of such a tool is essential when attempting to apply the Nogueira formal model, as it provides the capability to collect detailed information, over the software development lifecycle. The data can later be extracted and used for input to the Nogueira model metrics.

B. Analysis and enhancement to the functional description of the Mission Space Resource Center: DMSO developed the Functional Description of the Mission Space (FDMS) Resource Center under the guidance of DoD 5000.59-P, DoD Modeling and Simulation Master Plan. The FDMS Resource Center provides a controlled repository for modeling and simulation (M&S) data and promotes data standardization and reuse. The FDMS Resource Center is currently functional and on-line at http://38.241.48.9.

Use of the FDMS Resource Center is voluntary on the part of DoD M&S organizations, although maximum use of the Center is paramount if standardization and reuse synergies are to be realized. In an effort to encourage more use of the Resource Center's capabilities, we analyzed the Resource Center,

interviewed the Center's principals, and developed a set of recommendations governing screenshots appearance, data workflow control, and privilege permission selections to simplify and clarify the Center's user process:

1. The FDMS libraries will refer to the digital files in its repository as "products."
2. The Design and Create Documents screen will clarify the difference between "register" and "submit."
3. The Register New Products screen will clearly inform the user of his options regarding creating registration elements or registering products.
   - The screen will present the user with two options: to register a product or to create a registration element.
   - The screen will briefly define "registration element" so that the user can make an informed decision.
4. The FDMS system will control the creation of registration elements.
   - The Producer will not be able to use a registration element and it will not be visible to users other than the Administrator until it is approved by the governing Sponsor.
   - The FDMS system will overtly notify the governing Sponsor and Producer during the various steps in creating a registration element.
   - The Create Registration Element screen will clearly inform the user how to create a registration element. The screen will have a clear header and definition, will not have misleading underlining, and its top "Register" button will be labeled to reflect its true "go back one screen" function.
5. The FDMS system will control the submission of products for approval.
   - The system will overtly notify the governing Sponsor and Producer during the various steps in the submission of products for approval.
   - The top "Register" button on the Register Product(s) screen will be labeled to reflect its true "go back one screen" function.
6. The Product/Registration Element Approval screen will be clear.
   - The screen header will be correctly labeled.
   - The headers of the first and second columns of the approval table will read "Product/Registration Element" and "Sponsor", respectively.
7. The headers of the second and third columns of the approval table in the Product Endorsement screen will read "Sponsor" and "Endorsed", respectively.
8. A Sponsor will be able to define groups and assign privileges to those groups.
   - A Sponsor will be able to create and modify groups. Each group will have a unique name. The Sponsor will have the option to add notes or explanatory comments about a group. The system will display the names of users so that the Sponsor can select user names from the display to be members of his group. A Sponsor will have the option of allowing other users to use his group or of restricting all other users from using his group.
   - A Sponsor will be able to assign FDMS privileges to a group in the same manner as he would to an individual user.

The implementation of these recommendations into subsequent versions of the FDMS Resource Center will significantly improve the usability of the web-based repository and novice user's understanding of the organization and functionality of the FDMS Resource Center. This, in turn, will encourage members of the DoD modeling and simulation community to exploit the Resource Center by registering and analyzing their own products in the repository and by reusing other registered products. This anticipated synergy will directly support the first and fourth objectives of the draft DoD Modeling and Simulation Master Plan.

C. Evaluation of XML and Wrapper-based translators for heterogeneous DoD databases: In today's combat environment, the US military and its allies find themselves in the midst of the information age they helped to start. This information and applied systems abound in all parts of the services and at locations throughout the globe. To influence decisions, commanders and their respective staffs need the most up-to-date information available. This information comes from various sources, but especially from computer systems, many of which were developed over the last few decades before interoperability became a concern. These stovepipe systems cannot pass information to each other because they use incompatible message sets. We

developed an object-oriented model for a "wrapper-based" translator to resolve the representational differences between heterogeneous systems which include: (1) an integrated development environment for users to create such models, (2) methods for determining object correspondence during system integration, and (3) the use of the Extensive Markup Language (XML) as a means for establishing interoperability between multiple DoD databases.

D. Metrics for measuring the effectiveness of software testing tools: The levels of quality, maintainability, testability, and stability of software can be improved and measured through the use of automated testing tools throughout the software development process. Automated testing tools assist software engineers to gauge the quality of software by automating the mechanical aspects of the software-testing task. Automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Evaluating available tools and selecting the most appropriate suite of tools can be a difficult and time-consuming process. We proposed a suite of objective metrics for measuring tool characteristics as an aide in systematically evaluating and selecting automated testing tools for both procedural and object-oriented source code.

The proposed metrics for evaluating testing tools include:

1. Human Interface Design (HID) - This metric measures whether the tools have well designed human interfaces to enable easy, efficient, and accurate setting of tool configuration. A large HID indicates the level of complexity in learning the tool's procedures and the likelihood of errors in using the tool over a long period of time.
2. Maturity & Customer Base (MCB) - This metric measures the maturity of a tool, as indicated by the customer satisfaction in the tool's ability to adequately test their software.
3. Tool Management(TM) - This metric measures the ability of Automated testing tools to provide for several users to access the information while ensuring proper management of the information.
4. Ease of Use (EU) - Ease of use accounts for the learning time of first-time users, retainability of procedural knowledge for frequent and casual users, and operational time of frequent and casual users.
5. User Control (UC) - This metric measures the ability of the testing tools that provide users expansive control over tool operations. It enables testers to effectively and efficiently test those portions of the program that are considered to have a higher level of criticality, have insufficient coverage, or meet other criteria determined by the tester. UC is defined as the summation of the different portions and combinations of portions that can be tested.
6. Test Case Generation (TCG) - This metric measures the ability of the test tools to automatically generate and readily modify test cases, either based on parsing the software under test or on modification to the software under test.
7. Tool Support (TS) - This metric measures the degree of technical support provided by the vendor.
8. Estimated Return on Investment (EROI) - This metric measures the estimated gain in productivity, software quality, and testing cost reduction against cost of tool investment.
9. Reliability (Rel) - This metric measures the average mean time between tool failures.
10. Maximum Number of Classes (MNC) - This metric measures the maximum number of software classes that may be included in a tool's testing project.
11. Maximum Number of Parameters (MNP) - This metric measures the maximum number of parameters that may be included in a tool's testing project.
12. Response Time (RT)- Time required to conduct a test case on specified size of software.
13. Features Support (FS) - This metric measures features like extensibility, database availability, integration with software development environment, and summary report generation.

These metrics were applied to the three testing-tool suites. During the process, we discovered that several of the metrics are quite difficult, if not impossible, to calculate without having additional information supplied by the tool vendor. For example, if a vendor has not conducted a study on the tool's operational retainability by its users, experiments would need to be designed and conducted to evaluate the performance of users in applying the tools. If a vendor does not have statistics on its average response time to customer support requests, calculating the measure would be impossible. Success was achieved in applying several of the metrics including HID, TCG, and reporting features (RF). HID measurements were calculated for each testing tool based on the sub-metrics of average keyboard-to-mouse switches, average input fields per function, average length of input fields, and button recognition when applicable. The sub-

metrics demonstrated non-coarseness (different values were measured), finiteness (no metric was the same for all tools), and non-uniqueness (some equal values were obtained). The HID measurements were all unique, indicating that the measurement could be useful in comparing tools during the evaluation and selection process. TCG measurements also provided unique measurements for each tool. Sub-metrics measuring levels of automated test-case generation and test case reuse functionality demonstrated the qualities of non-coarseness, finiteness, and non-uniqueness. RF measurements were also successful. It is simple to determine whether a tool automatically generates summary reports (SR) that are viewable without the tool application running (e.g., HTML or ASCII text document). The RF metric is non-coarse, finite, and non-unique. However, because each tool earned a SR score of one, additional testing should be conducted to determine SR's level of non-uniqueness.

PUBLICATIONS:

Murrah, M., Johnson, C. and Luqi, "Enhancements and Extensions of Formal Models for Risk Assessment in Software Projects," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," *Proceedings of the 14th International Conference on Parallel and Distributed Computing Systems*, Dallas, TX, 8-10 August 2001.

Young, P., Berzins, V., Ge, J. and Luqi, "Use of Object Oriented Model for Interoperability Wrapper-Based Translator for Resolving Representational Differences between Heterogeneous Systems," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

THESIS DIRECTED:

Johnson, C. and Piirainen, R., "Application of the Nogeuria Risk Assessment Model to Real-Time Embedded Software Projects," Masters Thesis, Naval Postgraduate School, June 2001.

Nelson, P., "A Requirements Specification of Modifications to the Functional Description of the Mission Space Resource Center," Masters Thesis, Naval Postgraduate School, June 2001.

Kwang Kin, B., "A Simple Software Agents Framework for Building Distributed Applications," Masters Thesis, Naval Postgraduate School, March 2001.

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Pugh, R., "Methods for Determining Object Correspondence during System Integration," Master Thesis, Naval Postgraduate School, June 2001.

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DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Conceptual Modeling, Simulation and Specifications, Risk Assessment, Computer Software

DYNAMIC ASSEMBLY FOR SYSTEMS ADAPTABILITY, DEPENDABILITY, AND ASSURANCE (DASADA) PROJECT

Luqi, Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: For NPS to support DARPA's efforts with the DASADA project in software technology and development for future adoption in military systems. The expected benefits of the proposed effort are to facilitate the transition of DASADA technologies to military applications, to prepare young officers for technical missions involving such technologies, and to lower barriers between warfighters and technologies. It is an investment for the training of out future admirals

SUMMARY: Important results accomplished in 2001 include:

- Conducted critical study and review of the 19 DASADA projects,
- Educated DoD engineers and military officers on DASADA technologies via distance learning,
- Conducted in-depth case study of one the EDP programs,
- Developed checklist and template for DASADA technology evaluation,
- Developed a guide to help DoD managers to select software metrics in acquiring new technologies for weapon systems software.

A review of the DARPA functional requirements listed in the request for proposals as well as various DASADA briefs, white papers, periodicals, and other DoD on-line resources was conducted. In addition, analysis generated from the DASADA program conference held at the Naval Postgraduate School, Monterey, CA from 31 January-2 February 2001 was completed. An in-depth analysis of the 19 DASADA technologies was conducted during the DARPA-sponsored demonstration held in Baltimore 4-5 June 2001.

An in-depth study of the Managed Information and Network Exchange Router (MINER) program was performed and a template was developed to ensure standardization and serve as a metric for approval or disapproval of the implementation of the DASADA technology in a specific software system. The template diagrams the software architecture, the system components, desired functionality, and logical relationship among components with respect to the DASADA technologies.

During the fact-finding efforts at the "DASADA Demo Days" in Baltimore, Maryland, a significant amount of insight into the development status of each of the projects as well as comprehensive information into each of the technologies was attained. It was observed that some of the projects were aggressively coordinating with other technologies as well as working with an Experimental Demonstration Project (EDP). Several projects just recently matured their technology to the point where they were going to contact one of the EDPs in the near future for demonstration purposes. Lastly, there was a hand full of projects that were not even close to the development level to demonstrate their projects much less than working with an EDP in the near future. It was found that the technologies, which are currently coordinating with industry on the development of embedded software systems, are the most applicable to the original spirit of the DASADA Program. These technologies include:

- MetaH (modeling, timing analysis),
- UNCLE (constraint consistency gauges),
- QRAM (resource allocation gauges),
- IMPACT (system load tracking and visualization),
- Proteus (run time and design time gauges for alternate architecture deployment).

This analysis also concludes that there are particular web and network-based systems that in all likelihood will prove to be of considerable benefit to DoD. These technologies include:

- SIM-TABASSCO (component interoperability gauges),
- Kinesthetics eXtreme (probes and gauges for runtime monitoring of web-based systems),
- Venice tool (design time component assembly tool).

There were two aspects of the DASADA program that warrant mentioning due to their success; the first being that DARPA deemed the best method to achieve the program objective was to merge academia with DoD projects so that the developing technologies had readily available real-world projects to demonstrate their advanced technological capabilities. The second aspect was the exposure to DoD engineers of the state-of-the-art software engineering technology that the DASADA program exemplifies during the DASADA Winter Principal Investigator (PI) Meeting in January 2001. To facilitate the transfer of DASADA technologies to DoD users, we hosted the Winter PI meeting at the Naval Postgraduate School and arranged over 40 DoD engineers and military officers attended the meeting via distance learning.

A guide was also developed to help DoD managers on selecting the most effective set of software metrics to help DoD managers in acquiring new technologies for weapon systems software. The guide will be useful in helping DoD Managers to acquire future DASADA technologies.

THESIS DIRECTED:

Mandak, W. and Stowell, C., "Dynamic Assembly for System Adaptability, Dependability and Assurance (DASADA) Project Analysis," Masters Thesis, Naval Postgraduate School, June 2001.

Ramgolam, R., "A Guide to Selecting Software Metrics for the Acquisition of Weapon Systems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, DASADA

ENGINEERING AUTOMATION FOR RELIABLE SOFTWARE

Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: This research addresses the problem of how to produce reliable software that is also flexible and cost effective for the DoD distributed software domain. Current and future DoD software systems fall into two categories: Information systems and Warfighter systems. Both kinds of systems can be distributed, heterogeneous and network-based, consisting of a set of components running on different platforms and working together via multiple communication links and protocols. It was proposed to tackle the problem with a "wrap and glue" technology that is based on a domain specific distributed prototype model. The key to make this approach reliable, flexible, and cost-effective is the automatic generation of glue and wrappers based on the designer's specifications. Glue and wrappers are software that bridge the interoperability gap between individual COTS/GOTS components. Research was proposed on enabling technologies for this approach including prototyping, automatic program generation, inference for design checking, reliability assessment, and reliability improvement.

SUMMARY: The work focused on "wrap and glue" technology based on a domain specific distributed prototype model. The key to making the proposed approach reliable, flexible, and cost-effective is the automatic generation of glue and wrapper software based on a designer's specification. The proposed "wrap and glue" approach allows system designers to concentrate on the difficult interoperability problems and defines solutions in terms of deeper and more difficult interoperability issues, while freeing designers from implementation details. The objective of our research is to develop an integrated set of formal models and methods for system engineering automation. These results will enable building decision support tools for concurrent engineering.The research addresses complex modular systems with embedded control software and real-time requirements.

The longer-term goals are to construct an integrated set of software tools that can improve software quality and flexibility by automating a significant part of the process and providing substantial decision support for the aspects that cannot be automated. The resulting development environment should be adaptable to enable (1) maintaining integrated support in the presence of business process improvement, (2)

incorporation of future improvements in engineering automation methods, and (3) specialization to particular problem domains.

In FY01, models and methods were investigated for solving the integration and interoperability problems in component-based distributed heterogeneous systems development.

The work resulted in models and languages for specifying the architecture of distributed heterogeneous systems and components, as well as technologies and tools to automate the integration of distributed heterogeneous software component via the automatic generation of glue and wrappers from specifications.

An object-oriented model for a wrapper-based translator was developed to resolve the representational differences between heterogeneous systems; an integrated development environment for users to create such models; methods for determining object correspondence during system integration; and the use of the Extensive Markup Language (XML) as a means for establishing interoperability between multiple DoD databases. Techniques were also developed for decision support for optimizing distributed object servers utilization, as well as the use software decoys to improve the security of distributed heterogeneous systems.

In addition, formal risk assessment models were investigated for the evolutionary software process. Methods and tools were formulated to assess the risk and the duration of software projects automatically, based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. The effectiveness of the models was validated by comparing the results of the models against data collected from 3 large real projects and 16 simulated projects.

Investigators worked with the U.S. Army TACOM to develop formal models and methods to assess the maturity/risk of emerging software technologies and to assist managers to size the software technology infrastructure.

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THESIS DIRECTED:

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DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Engineering Automation, Reliability, Glue and Wrapper Technology, Computer-Aided Decision Support

IMPROVED SOFTWARE TECHNOLOGY FOR THE NEXT GENERATION AIRCRAFT CARRIER

Luqi, Professor
Department of Computer Science
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of the proposed project is to improve software technology in areas of concern to NAVSEA, and to apply the results to software issues arising in future aircraft carriers such as CVX. For example, we will investigate better ways to achieve software interoperability among aircraft carrier systems, and to identify and mitigate software-related risk factors in the early stages of the project, when requirements are fluid and detailed designs are not yet available.

SUMMARY: A. XML and Wrapper-based translators for system interoperability: In today's combat environment, the U.S. military and its allies find themselves in the midst of the information age they helped to start. This information and applied systems abound in all parts of the services and at locations throughout the globe. To influence decisions, commanders and their respective staffs need the most up-to-date information available. This information comes from various sources, but especially from computer systems, many of which were developed over the last few decades before interoperability became a concern. These stovepipe systems cannot pass information to each other because they use incompatible message sets.

An object-oriented model for a "wrapper-based" translator was developed to resolve the representational differences between heterogeneous systems, which solves the data and operation inconsistency problem in legacy systems based on an Object-Oriented Model for Interoperability (OOMI). A Federation Interoperability Object Model (FIOM) is defined for a specific federation of systems designated for interoperation. The data and operations to be shared between systems are captured in a number of Federation Interoperability Classes (FICs) used to define the interoperation between legacy systems. Software wrappers are generated according to the FIOM that enable automated translation between different data representations and operation implementations. We also studied the use of XML-based message translation for implementation of the proposed model. The capability provided by the XML family of tools coincides nicely with the requirement for data and operation representation capture and translation.

B. Interoperability model for re-engineering legacy software: Legacy software systems in the Department of Defense (DoD) have been evolving and are becoming increasingly complex while providing more functionality. The shortage of original software designs, lack of corporate knowledge and software design documentation, unsupported programming languages, and obsolete real-time operating system and development tools have become critical issues for the acquisition community. Consequently, these systems are now very costly to maintain and upgrade in order to meet current and future functional and nonfunctional requirements.

A new interoperability model for re-engineering of old procedural software of the Multifunctional Information Distributed System Low Volume Terminal (MIDS-LVT) to a modern object-oriented architecture was developed. In the MIDS-LVT modernization acquisition strategy, only one Computer Software Configuration Item (CSCI) component at a time will be redesigned into an object-oriented program while interoperability with other unmodified CSCIs in the MIDS-LVT distributed environment must be maintained. Using this model, each legacy CSCI component can be redesigned independently without affecting the others. Lessons learned from this re-engineering effort will benefit future integration of legacy software in CVX and other DoD systems.

C. Quantitative risk assessment for software development: Formal risk assessment models and methods for the evolutionary software process and their application to CVX and DoD projects were investigated. The methods and tools to assess the risk and the duration of software projects automatically were analyzed and tested, based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. These metrics eliminate the subjectivity issue characteristic of previous research. Any decision-maker will arrive at the same estimates, independent of his or her expertise. The approach enables a project manager to evaluate the probability of project success very early in the life cycle. For more than twenty years the estimation standards (COCOMO 81, COCOMO II, Putnam) have been characterized by the common limitation that the requirements should be frozen in order to make estimations. The models remove this limitation, facing the reality that requirements are inherently variable. The effectiveness of the models was validated by comparing the results of the models against data collected from 16 simulated projects and 3 large, real projects.

1. Sixteen Simulated Projects: The simulations showed that the three risk factors observed during the causal analysis (efficiency, requirements volatility, and complexity) have compound effects over the three parameters of the Weibull distribution. The results of the models were illustrated against 16 simulated projects. Each model derives an increasing degree of accuracy based on: metrics from the three risk factors, Weibull cumulative density function, and the derivation of the time.
    - Models 1-2: Model 1 can be used when the requirements volatility is small. Model 2 considers the three factors (EF, RV, and CX), but neglects the combined effect of EF and RV. Figure 1 illustrates the results of the models that were calculated using 95% of

confidence (p=0.95). Note the errors as vertical segments between the estimated and real values.

- Model 3: Model 3, illustrated in Figure 2, considers the three factors as well as the combined effects of EF and RV. The analysis of variance shows that the samples obtained from the simulations and the samples obtained from the estimates using Model 1, 2 or 3 cannot be statistically differentiated.

  Another interesting result is that the errors remain in the range of ±15% for all of the scenarios. This result is interesting if we compare it with the results of COCOMO (±20% in the best cases). Barry Boehm in reference to the validation of COCOMO said, "In terms of our criterion of being able to estimate within 20% of projects actuals, Basic COCOMO accomplishes this in only 25% of the time, Intermediate COCOMO 68% of the time, and Detailed COCOMO 70% of the time."
- Model 4: Model 4, Figure 2, can be used for any range of complexity and requirements volatility, and considers the three factors, their combined effects, and the following a priori assumptions:
  * A project with 0 LGC will take 0 days
  * (, (, and (> 0
  * If RV increases the p(x<=t) decreases
  * If CX increases then p(x<=t) decreases
  * If EF increases then p(x<=t) increases

  The scatter plot derived compares the simulated times versus the estimated times. Most of the errors are overestimations and the duration of the project has no effect over the percentage of error. Model 4 is conservative. The maximum overestimation error was less than 16% and the maximum underestimation was less than 4%.

  Model 4 gives a good estimation for projects between 4,000 and 20,000 LGC (128 and 640 KLOC of ADA). The estimation seems to be too optimistic for projects smaller than 1000 LGC but it is quite good for larger projects.

2. Uruguayan Navy Project: Model 4 was applied on a war-gaming simulator with 75,240 lines of code. The software was made up of 1836 LGC and was developed in 1.5 years by the Uruguayan Navy. Model 4 predicts 17 months instead of 18 months, the actual development time.
3. U.S. DoD Project A: This project used an Evolutionary Spiral lifecycle model. It used Object-Oriented methodology and was composed of five computer software configuration items written in ADA. It was real-time embedded, and used Rational Rose as a Computer Aided Software Engineering tool with the developer operating at SEI level 3. In addition, software metrics from three builds over a period of three years had been kept.

   Model 4 was used to calculate the probability of completion curve for the project. For consistency, we used working days, defined as 22 days per month, the same as used in the original Nogueira model.

   The model predicted that the minimum time, in days, necessary to have a probability of completion of 100% is approximately 260 working days. When compared to the actual time it took, which was 336 working days, the model predicted completion sooner. The model predicted 76 working days less, or a 22.6% delta: (1 - (260 / 336)) (100) = 22.6%.

   At this point, with 22.6% variability, we decided to investigate and see what the original estimated completion date was from project records. The original estimation was 200 working days, with the project schedule slipping 136 working days for build 3. The developer missed the original completion estimation by 40.5%: (1- (200 / 336)) (100) = 40.5%.

   The Nogueira model missed the developer's original estimate by 23.1%: (1-(200 / 260)) (100) = 23.1%.

   This data point leaves us with an inconclusive position as to the validation of the model against the first project. It appears that there is a difference when using projects with real data versus simulated project data, reflecting what the real world is - unpredictable.
4. U.S. DoD Project B: This project originally used an incremental build lifecycle model and not an evolutionary model. It originally used Functional Decomposition methodology and was composed of six Computer Software Configuration Items. Written in ADA and assembly language, it was real-time embedded. It did use upper CASE tools, like Requirements Traceability Matrix (RTM), however did not use lower CASE tools such as Rational Rose. The development effort initially

was performed in an ad-hoc manner with little software process involved and had experienced extreme volatility and poor metrics early in its development. However, due to a major restructure and overhaul of the project, and a shift of focus to institutionalizing software processes, (SEI CMM level 3 certification), the project migrated to Ada, and began using a modified Incremental Build lifecycle model. In addition, suitable software metrics from two recent builds were available. We used Dr. Nogueira's Model 4 to calculate the probability of completion curve for Build 2 using; BR=2.59, DR=3.04, RV=5.63, O=2544, D=4010, T=1003. The model predicted Impossible.

Actual time for build 2 took from 4/24/00 until 7/10/00 or 68 working days at 22 working days a month. We believe this inconsistency is due primarily to the calculation for the LGC count being based on all six Computer Software Configuration Items (CSCI). Core functionality on three CSCIs; CSCI-A, CSCI-B, and CSCI-C had been previously developed and validated. However, the builds during this period, involved addition of functionality to the following CSCIs: CSCI-D, CSCI-E, and CSCI-F. That is, build 2 was modifying only a portion of the total software system code, but the LGC data gives a view of all six CSCIs combined.

The available data was not broken down into separate CSCIs, nor did it, post-mortem, identify the code that was being worked in a previous software release. We cannot fault the developer for not collecting metrics for research concepts that they are not aware of, nor do we believe that this type of data collection is a requirement of CMM level 3.

A finding of this research is the need to adjust the CX when applying the Nogueira model to evolved projects that are developing or enhancing only a portion of their CSCIs.

As previously stated, this project did not utilize a lower case tool such as Rational Rose. We believe use of such a tool is essential when attempting to apply the Nogueira formal model, as it provides the capability to collect detailed information, over the software development lifecycle. The data can later be extracted and used for input to the Nogueira model metrics.

D. Metrics for Weapon Systems Acquisition: Modernization of Department of Defense (DoD) weapon systems has resulted in an ever-increasing dependence on software. Despite technological advances in the software field, software development remains costly and one of the highest risk factors on most weapon system programs. The use of software metrics is a methodology for mitigating this uncertainty so that software development progresses under informed decision making. Software metrics are essential tracking tools used by program managers to monitor and control risk areas. However, the choice of metrics for a program is critical to their usefulness. We developed a guide to acquisition managers on selecting the most effective metrics to use in management of weapon system software. The study identified key issues in the use of software metrics experienced by program managers, and recommends a revised set of metrics and improvements to the use of metrics based on innovations and improvements in the software field as well as software estimation tools that facilitate the use of these software metrics.

E. Electronic maneuvering board and dead reckoning tracer decision aid for the Officer of the Deck: The U.S. Navy currently bases the majority of our contact management decisions around a time and manning intensive paper-based Maneuvering Board process. Additional manning requirements are involved on many Naval Ships in order to accurately convey the information to the OOD and/or the Commanding Officer. When given situations where there exist multiple contacts, the current system is quickly overwhelmed and may not provide Decision-Makers a complete and accurate picture in a timely manner.

A stand-alone system was developed that provides timely and accurate contact information for decision-makers. By creating a reliable, automated system in a format that is familiar to all Surface Warfare Officers we will provide the Navy with a valuable decision-making tool, while increasing ease of data exchange and reducing current redundancies and manning inefficient practices.

The software design is based upon the Unified Modeling Language (UML). UML allows us to construct a software model that is supported by the ADA programming language. Our design is based upon these fundamental tenants: Non-Operating System dependent, Non-Hardware System dependent, Extensible and Modular design. ADA provides a certified compiler, making our code robust and assuring the "buyer" that the program does what we advertise it to do.

F. Metrics for measuring the effectiveness of software testing tools: The levels of quality, maintainability, testability, and stability of software can be improved and measured through the use of automated testing

tools throughout the software development process. Automated testing tools assist software engineers to gauge the quality of software by automating the mechanical aspects of the software-testing task. Automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Evaluating available tools and selecting the most appropriate suite of tools can be a difficult and time-consuming process. We proposed a suite of objective metrics for measuring tool characteristics as an aide in systematically evaluating and selecting automated testing tools for both procedural and object-oriented source code.

The proposed metrics for evaluating testing tools include:

1. Human Interface Design (HID) - This metric measures whether the tools have well designed human interfaces to enable easy, efficient, and accurate setting of tool configuration. A large HID indicates the level of complexity in learning the tool's procedures and the likelihood of errors in using the tool over a long period of time.
2. Maturity & Customer Base (MCB) - This metric measures the maturity of a tool, as indicated by the customer satisfaction in the tool's ability to adequately test their software.
3. Tool Management(TM) - This metric measures the ability of Automated testing tools to provide for several users to access the information while ensuring proper management of the information.
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12. Response Time (RT)- Time required to conduct a test case on specified size of software.
13. Features Support (FS) - This metric measures features like extensibility, database availability, integration with software development environment, and summary report generation.

These metrics were applied to the three testing-tool suites. During the process, we discovered that several of the metrics are quite difficult, if not impossible, to calculate without having additional information supplied by the tool vendor. For example, if a vendor has not conducted a study on the tool's operational retainability by its users, experiments would need to be designed and conducted to evaluate the performance of users in applying the tools. If a vendor does not have statistics on its average response time to customer support requests, calculating the measure would be impossible. Success was achieved in applying several of the metrics including HID, TCG, and reporting features (RF). HID measurements were calculated for each testing tool based on the sub-metrics of average keyboard-to-mouse switches, average input fields per function, average length of input fields, and button recognition when applicable. The sub-metrics demonstrated non-coarseness (different values were measured), finiteness (no metric was the same for all tools), and non-uniqueness (some equal values were obtained). The HID measurements were all unique, indicating that the measurement could be useful in comparing tools during the evaluation and selection process. TCG measurements also provided unique measurements for each tool. Sub-metrics measuring levels of automated test-case generation and test case reuse functionality demonstrated the qualities of non-coarseness, finiteness, and non-uniqueness. Reporting features (RF) measurements were also successful. It is simple to determine whether a tool automatically generates summary reports (SR) that are viewable without the tool application running (e.g., HTML or ASCII text document). The RF metric is

non-coarse, finite, and non-unique. However, because each tool earned a SR score of one, additional testing should be conducted to determine SR's level of non-uniqueness.

PUBLICATIONS:

Young, P., Berzins, V., Ge, J. and Luqi, "Use of Object Oriented Model for Interoperability Wrapper-Based Translator for Resolving Representational Differences between Heterogeneous Systems," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," *Proceedings of the 14th International Conference on Parallel and Distributed Computing Systems*, Dallas, TX, 8-10 August 2001.

Murrah, M., Johnson, C. and Luqi, "Enhancements and Extensions of Formal Models for Risk Assessment in Software Projects," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

THESIS DIRECTED:

Bossuyt, B. and Snyder, B., "Software Testing Tools: Metrics For Measurement Of Effectiveness On Procedural And Object-Oriented Source Code," Masters Thesis, Naval Postgraduate School, September 2001.

Christie, B. and Young, P., "Integrated Development Environment (IDE) for the Construction of a Federation Interoperability Object Model (FIOM)," Masters Thesis, Naval Postgraduate School, September 2001.

Davis, D., "Evaluation of the Extensive Markup Language (XML) as a Means for Establishing Interoperability Between Multiple DoD Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Frantzen, J. and Ehresman, K., "Electronic Maneuvering Board and Dead Reckoning Tracer Decision Aid for the Officer of the Deck," Masters Thesis, Naval Postgraduate School, September 2001.

Halle, R., "Extensible Markup Language (XML) Based Analysis and Comparison of Heterogeneous Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Kwang Kin, B., "A Simple Software Agents Framework for Building Distributed Applications," Masters Thesis, Naval Postgraduate School, March 2001.

Johnson, C. and Piirainen, R., "Application of the Nogeuria Risk Assessment Model to Real-Time Embedded Software Projects," Masters Thesis, Naval Postgraduate School, June 2001.

Moua, T., "Application Programmer's Interface (API) for Heterogeneous Language Environment and Upgrading the Legacy Embedded Software," Masters Thesis, Naval Postgraduate School, September 2001.

Pugh, R., "Methods for Determining Object Correspondence during System Integration," Masters Thesis, Naval Postgraduate School, June 2001.

Ramgolam, R., "A Guide to Selecting Software Metrics for the Acquisition of Weapon Systems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software, Computer Technology, Interoperability, C4ISR, Combat Systems, CVX

MONTEREY WORKSHOP 2001 - ENGINEERING AUTOMATION FOR SOFTWARE INTENSIVE SYSTEM INTEGRATION

Luqi, Professor
Department of Computer Science
Sponsors: Office of Naval Research, Defense Advanced Research Projects Agency, U.S. Army Research Office, U.S. Air Force Office of Scientific Research

OBJECTIVE: This workshop is aimed at the dissemination and integration of recent research results related to the production of reliable cost-effective software for DoD in heterogeneous environments. A major goal for this workshop is to help the software engineering community focus on issues that are vital to improving the state of software engineering practice. This workshop focuses on all topics related to supporting engineering automation of reliable cost-effective integrated distributed software development processes. The purposes of the workshop are to assess current research efforts in this area, to identify results and directions that can increase the degree of automation, to aid tool integration by building a common understanding, and to increase the practical use of formal methods.

SUMMARY: The 2001 Monterey Workshop on Engineering Automation for Software Intensive System Integration is the 8th in a series of International workshops. The workshop was held in Monterey, California during 18-22 June 2001. The general theme of the workshop has been to present and discuss research works that aims at increasing the practical impact of formal methods for software and systems engineering. The particular focus of this workshop was "Engineering Automation for Software Intensive System Integration." Previous workshops have been focused on issues including, "Real-time and Concurrent Systems," "Software Merging and Slicing," "Software Evolution," "Software Architecture," "Requirements Targeting Software," and "Modeling Software System Structures in a Fast Moving Scenario."

A major goal for this series of workshops is to encourage the software engineering community in general to improve interaction between researchers and engineering practitioners. The workshop has long established itself as a summit where researchers from academics and industries can exchange recent results, assess their significance and earn motivation for transferring the relevant results to practice. This indeed is a forum where software engineers may communicate current problems in engineering practice to researchers and help focus to bridge the gap between the theoretical and practical sides of the subject.

It is no longer the case that theoretical foundations for computing are lacking. However, keeping in mind the challenge to put these results to work, the formal aspects of computing cannot be studied in isolation in the context of software engineering. The need to ensure that the assumptions on which formal models are based are consistent with the situations encountered in practical applications puts interdisciplinary requirements on researchers and lends importance to interactions between experts from heterogeneous backgrounds.

This year, apart from the distinguished panel of invited speakers, we have accepted contributed papers mainly to encourage the emerging researchers in software engineering. This has widened the scope of discussion and the sessions were highly interactive and rich with intellectual frictions in opinion from a broad range of experts. Members of the academic, government, military and commercial world exchanged their vision, insight and concerns on many important issues. The workshop has provided another step to reduce the gap between theory and practice of software engineering.

PUBLICATION:

Luqi, "Engineering Automation for Software Intensive System Integration," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, Automation, Research Assessment, System Integration

PERFORMANCE MEASUREMENT OF THE METCAST SERVER

Luqi, Professor
Department of Computer Science
Sponsors: Fleet Numerical Meteorology and Oceanography Center, and Space and Naval Warfare Systems Center – San Diego

OBJECTIVE: To measure the performance of the metcast server under real loads. Discover characteristics of the metcast connection loads and compare with business-to-consumer loads. Develop a benchmarking tool that reproduces metcast loads. Use the tool to micro-benchmark the server and suggest areas of improvement.

SUMMARY: Important results accomplished in 2001 include:

- Configured Metcast (the server and the obs decoder) on several Linux boxes. Used one box to run a set of performance texts. The other two Linux boxes serve as a development Metcast server.
- Developed a new version of Metcast Channels, which supports product attributes and has many performance enhancements. The version is backward compatible. The new version has been thoroughly documented.
- Participated in a Joint METOC Data Standard meeting and contributed to the development of Joint METOCV XML standard. Developed a draft JMGRIB format to markup gridded data

PUBLICATIONS:

Kiselyov, O., "Distributing Weather Products through an HTTP Pipe," 1 February 2001, http://zowie.metnet.navy.mil/~spawar/JMV-TNG/

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, Automation, Metcast Server

SYSTEM ENGINEERING AND EVOLUTION DECISION SUPPORT

Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: The objective of this effort is to develop a scientific basis for system engineering automation and decision support. This objective addresses the long term goals of increasing the quality of service provided by complex systems while reducing development risks, cost, and time. The effort focuses on decision support for designing operations of complex modular systems that can include embedded software. Emphasis areas include engineering automation capabilities in the areas of design modifications, design records, reuse, and automatic generation of design representations such as real-time schedules and software.

SUMMARY: Focused was on automation of design activities that appear in an evolutionary approach to system development. Decision support for design synthesis, reuse and evolution is emphasized. This research extended recently developed formal methods in system engineering to construct a cohesive set of formal models. These models are used to create and to connect automated processes for computer aided prototyping, requirements validation, and design synthesis. Mathematical models for implementing a set of automated and integrated engineering automation tools were also developed. Work combined very-high-level specification abstractions and concepts with: (1) formal real-time models, (2) automated management of system design data and human resources, (3) design transformations, (4) change merging, (5) automated retrieval of reusable system design components, and (6) automated schedule construction. We have created automated methods for: (1) generating real-time control programs, (2) generating simulations of subsystems, and (3) coordinating concurrent work by engineering teams. Work will ensure design consistency and alleviate communication difficulties.

The significance of the work is to:

- improve system effectiveness and flexibility,
- increase engineering productivity, and
- reduce system maintenance costs.

This was achieved by providing a higher level of engineering automation coupled directly with requirements validation facilities. The work will broaden the scope of engineering decision support to include concurrent whole-system engineering, requirement determination, and system evolution. Automated decision support will ensure system quality by decreasing the human effort required. This, in turn, will minimize the incidence of human error. The trial use of operational system prototypes linked with software simulations of selected subsystems enables users to provide feedback for validation and refinement of system requirements prior to detailed design. Maintenance costs can be minimized by reducing the need to repair requirement errors after system deployment. Methods for process and system re-engineering at minimal cost were provided This was achieved by: (1) regenerating new variations of designs from high-level decisions. (2) combining changes, and (3) propagating the consequences of design modifications. These engineering capabilities will enable the Army to improve and integrate its complex systems with reduced costs. Improved systems can reduce Army manpower needs while strengthening information warfare capabilities.

Specific tasks accomplished include:

- Formal models, architecture and tools for software evolution: A new relational hypergraph model, architecture and tools for the computer-aided software evolution process was developed. The new model provides an integrated framework for integrating software evolution activities with configuration control, maintaining the consistency of an evolving system, organizing and coordinating the activities involved in the evolution of large systems. The model also serves as the basis for organizing the repository of configurations. The effectiveness of the model was illustrated via a case study involving C4I systems evolution.
- Formal model for software project risk assessment: Formal risk assessment models for the evolutionary software process, and methods and tools were developed to assess the risk and the duration of software projects automatically based on measurements (requirements volatility, production team efficiency, and product complexity) that can be obtained early in the development process. The effectiveness of the models was validated by comparing the results of the models against data collected from 3 large real projects and 16 simulated projects.
- Architectures and automated retrieval methods for software reuse: Formal models and methods to automate the search and retrieval of software components from software reuse repositories were developed. Models to support reuse in product line approach were also developed.
- The use of Computer Aided Prototyping in Software Re-engineering: The effective use of computer-aided prototyping techniques were studied for re-engineering legacy software via a case study involving the development an object-oriented modular architecture for the existing US Army Janus(A) combat simulation system, and validating the architecture via an executable prototype using the Computer Aided Prototyping System (CAPS). The research showed that prototyping can be a valuable aid in re-engineering of legacy systems, particularly in cases where radical changes to system conceptualization and software structure are needed.
- Automation support for distributed heterogeneous systems engineering: Models and methods for solving the integration and interoperability problems in component-based distributed heterogeneous systems development were investigated.

  The work resulted in models and languages for specifying the architecture of distributed heterogeneous systems and components, as well as technologies to automate the integration of distributed heterogeneous software component via the automatic generation of glue and wrapper from specification.

  An object-oriented model for an interoperability wrapper-based translator was developed to resolve the representational differences between heterogeneous systems, an integrated development environment for users to create such models, methods for determining object correspondence during system integration, and the use of the Extensive Markup Language (XML) as a means for establishing interoperability between multiple DoD databases.

Techniques were also developed for maximizing the network infrastructure and provide decision support for optimizing distributed object servers utilization, as well as the use software decoys to improve the security of distributed heterogeneous systems.

- Formal models for Technology Transition: Investigators worked with the U.S. Army TACOM to develop formal models and methods to assess the maturity/risk of emerging software technologies and to assist managers to size the software technology infrastructure.
- Technology transfer via Software Engineering education: To allow corporate and Department of Defense (DoD) software leaders and practitioners to effectively utilize the technology available to them, two Software Engineering graduate degree programs were developed to address the issues and needs unique to DoD software development. The Software Engineering program at the Naval Postgraduate School offers M.S. and Ph.D. degrees in Software Engineering to both in-residence and distance-learning students, to equip software leaders and practitioners with the tools needed to achieve information superiority. The Ph.D. Program is the first-ever doctoral program in Software Engineering. It is designed to satisfy the great and growing demand within the Department of Defense for Ph.D. level leadership to direct software research and development projects and to develop policies regarding software requirements and processes for design, evolution, reuse and management.

PUBLICATIONS:

Auguston, M., "Visual Meta-Programming Notation," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," *Proceedings of the 14th International Conference on Parallel and Distributed Computing Systems*, Dallas, TX, 8-10 August 2001.

Kiselyov, O., "Subclassing Errors, OOP & Practically Checkable Rules to Prevent Them," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Luqi, Berzins, V. and Shing, M., "The Use of Computer-Aided Prototyping for Reengineering Legacy Software," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Luqi, Berzins, V., Ge, J., Shing, M., Auguston, M., Bryant, B. and Kin, B., "DCAPS - Architecture for Distributed Computer Aided Prototyping System," *Proceedings of the 12th IEEE International Workshop on Rapid System Prototyping (RSP2001)*, pp. 103-108, Monterey, CA, 25-27 June 2001.

Michael, J. and Riehle, R., "Intelligent Software Decoys," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Murrah, M., Johnson, C. and Luqi, "Enhancements and Extensions of Formal Models for Risk Assessment in Software Projects," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Raje, R., Auguston, M., Bryant, B., Olson, A. and Burt, C., "A Unified Approach for the Integration of Distributed Heterogeneous Software Components," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Ray, W. and Berzins, V., "Optimization of Distributed Object-Oriented Servers," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Saboe, M. and Luqi, "A Software Technology Transition Engine," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

Young, P., Berzins V., Ge, J. and Luqi, "Use of Object Oriented Model for Interoperability Wrapper-Based Translator for Resolving Representational Differences between Heterogeneous Systems," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

THESIS DIRECTED:

Kwang Kin, B., "A Simple Software Agents Framework for Building Distributed Applications," Masters Thesis, Naval Postgraduate School, March 2001.

Davis, E., "Evaluation of the Extensive Markup Language (XML) as a Means for Establishing Interoperability Between Multiple DoD Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Halle, R., "Extensible Markup Language (XML) Based Analysis and Comparison of Heterogeneous Databases," Masters Thesis, Naval Postgraduate School, June 2001.

Johnson, C. and Piirainen, R., "Application of the Nogueira Risk Assessment Model to Real-Time Embedded Software Projects," Masters Thesis, Naval Postgraduate School, June 2001.

Mandak, W. and Stowell, C., "Dynamic Assembly for System Adaptability Dependability and Assurance (DASADA) Project Analysis," Masters Thesis, Naval Postgraduate School, June 2001.

Nelson, P., "A Requirements Specification of Modifications to the Functional Description of the Mission Space Web-based Tool," Masters Thesis, Naval Postgraduate School, June 2001.

Pugh, R., "Methods for Determining Object Correspondence during System Integration," Masters Thesis, Naval Postgraduate School, June 2001.

Windhurst, W., "An Application of Role-Based Access Control in an Organizational Software Process Knowledge Base," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: System Engineering, Decision Support, Evolution, Concurrent Engineering

WEAPON SOFTWARE SAFETY PROGRAM IN NPS SOFTWARE ENGINEERING AUTOMATION CENTER

Luqi, Professor
Department of Computer Science
Sponsors: Naval Sea Systems Command

OBJECTIVE: For Software Engineering Automation Center at the Naval Postgraduate School to support instructional effort for Software Engineering Courses on weapon software safety in software engineering curriculum, and to establish a weapon software safety chair and computer/telecommunication support.

SUMMARY: Modern weapon systems rely on software for virtually all aspects of their functionality. Software controls almost all aspects from the detection and classification of threats to launching the ordnance, guiding it to the threat, and, in some cases, initiating the explosive warhead. An error or failure in any of the software modules controlling the weapon system could have catastrophic results from

misidentifying a friendly track as hostile to initiating the warhead while still in close proximity to the launching platform.

The Navy needs highly trained individuals capable of developing and assessing the software for modern weapon systems to ensure that it can reliably perform its mission without posing an unacceptable risk to the fleet. Weapon Systems Software Safety is a discipline that integrates Systems Engineering, System Safety Engineering, and Software Engineering into a cohesive discipline that provides the knowledge and skills necessary to perform this risk assessment. The discipline is Software Engineering intensive due to the complexity of the software in modern weapon systems however; it uses a true Systems Engineering approach to address the issues. The proposed curriculum will provide a cadre of individuals trained in the development of critical software with the fundamental knowledge necessary to develop software that provides and acceptable level of risk in the system and operational context without sacrificing mission effectiveness or functionality. Key courses in the curriculum will also provide individuals with the knowledge and skills necessary to perform the required design, analysis, testing, and risk assessment to verify the safety of the software in the system context.

Software Engineering and Information Technology are rapidly evolving disciplines. The Naval Postgraduate School is at the forefront of both disciplines. To be effective, the Weapon Systems Software Safety must evolve with these disciplines and provide the direction necessary to maintain both the effectiveness and safety of the associated technology as it is applied to Navy weapon systems. NPS is in an enviable position to accomplish that mission. Qualified individuals must also perform both the theoretical and applied research necessary to provide the Weapon System Safety community with the tools and techniques necessary to assess the risk associated with the introduction of new technologies, the integration of existing technologies with our existing systems, as well as the integration of existing system into systems of systems. The students at NPS have backgrounds directly relevant to the discipline: many have first hand experience with the software developed for modern weapon systems. Therefore, NPS has a cadre of highly skilled individuals available to conduct this vital research.

The student body consists of individuals who will be managing weapon system programs involving software, managing the development of software for future weapon systems, or perhaps even developing the software themselves. The position will allow the direction of thesis and research topics to provide the necessary tools and techniques to evaluate software in complex weapon systems. The position will also allow direct access to research conducted at NPS and other universities in Software Engineering and Information Technology and evaluate its application, or possible impact, on the safety of modern weapon systems. Evaluating this research gives the Navy the opportunity to address these topics before they become a part of a Navy weapon system.

THESIS DIRECTED:

Brown, M., "Modeling and Reasoning about Safety Properties for Systems Interoperability and Systems of Systems," draft dissertation, Naval Postgraduate School.

Williams, C., "A Formal Application of Safety and Risk Assessment in Software Projects," draft dissertation, Naval Postgraduate School.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Engineering, Weapon Systems Software Safety, Automation

FY01 IO/IW RESEARCH ON INTELLIGENT SOFTWARE DECOYS

Bret Michael, Associate Professor
Department of Computer Science
Sponsor: Naval Information Warfare Activity

OBJECTIVE: Further investigate the technical feasibility of an intelligent software decoy architecture for use in information warfare.

SUMMARY: The notion of an intelligent software decoy was developed, providing both an architecture and initial description of an event-based language for automatic implementation of decoys. The decoys detect and respond to patterns of suspicious behavior, and maintain a repository of rules for behavior patterns and decoying actions. In order to illustrate our concept and approach, a model was constructed of system behavior from an initial list of event types and their attributes in the interaction between computer worms and an operating system. The model represents patterns of suspicious or malicious events that the software decoy should detect, and specific actions to be taken in response. The approach explicitly treats both standard and nonstandard invocations of components, with the latter representing an attempt to circumvent the public interface of the component.

At present various decoying strategies are being explored and the decoying action language is being expanded with the aim of supporting information operations and warfare. We are also implementing the event-based language, with the aim of running experiments using the language to test decoying strategies, and conduct performance analyses with the aim of determining the amount of overhead that will be generated by the decoying mechanism.

PUBLICATIONS:

Michael, J.B. and Riehle, R.D., "Intelligent software decoys," *Proceedings of Monterey Workshop: Engineering Automation for Software Intensive System Integration*, pp. 178-187, Naval Postgraduate School, Monterey, CA, June 2001.

PRESENTATIONS:

Michael, J.B., Auguston, M., Rowe, N.C. and Riehle, R.D. "Software Decoys: Intrusion Detection and Countermeasures," *Proceedings of Info Assurance Workshop*, IEEE, West Point, NY, June 2002, in press.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Behavior Modeling, Computer Security, Computer Worm, Event Trace, Software Decoy, Intrusion Detection, Intrusion Tolerance

TESTING OF LARGE SOFTWARE-INTENSIVE SYSTEMS

Bret Michael, Associate Professor
Department of Computer Science
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of the research project is threefold: (i) To provide expertise to SPAWAR corporation in the area of software testing, and more generally, formal verification and validation, in both overseeing and participating in the Defense Systems Test and Productivity Initiative (DSTPI). This objective entails two tasks: identifying key areas of research and technology transfer that the DSTPI should address and overseeing the research performed by the University of South Florida as part of the DSTPI to ensure that the research is relevant to the needs of SPAWAR, the Department of the Navy (DoN), and the Department of Defense (DoD). (ii) To integrate the outcomes and general deliverables of the DSTPI, as appropriate, into the computer science and software engineering curricula at the Naval Postgraduate School to SPAWAR, as well as to transfer the results of the curriculum development and research by faculty and students at the School to SPAWAR, the DoN, and DoD. The transfer of outcomes and general deliverables to the curricula will assist the School in preparing naval officers to return to the Fleet with the latest theory and knowledge of best practices to specify and acquire software that is testable, of known pedigree, and maintainable. In the other direction, the faculty and students can transfer their research result on testing, and more generally, formal verification and validation of software-intensive systems, to the other participants in the DSTPI. In order to facilitate the exchange of technology and influence the direction of the DSTPI, Dr. Michael will participate as a member of the Advisory Board of the DSTPI. (iii)To perform research on a novel approach to testing large software-intensive systems. Dr. Michael, along with Dr. Neil Rowe and a team of graduate students, are investigating the technical feasibility of testing policy and system requirements with the goal of detecting gaps (e.g., inconsistencies in policy or requirements) prior

to refining policy into requirements, and requirement into lower-level system artifacts (e.g., architectures, designs, code, documentation) [2,3]. We believe that our approach to testing systems can significantly improve the ability of the DoD to both acquire and maintain high-quality software for large systems. This work is based on the concept of a policy workbench [5]: an integrated set of tools for specifying policy and requirements, testing policy and requirements, refining policy and requirements into executable or interpretable specifications, and maintaining the policy, requirements, and other system artifacts.

SUMMARY: A suite of objective metrics was developed for measuring the characteristics of automated software-testing tools, as an aid for systematically evaluating and selecting automated testing tools. The metrics are independent of architectural frameworks and lower level software system artifacts. Such metrics are needed because automated testing tools vary in their underlying approach, quality, and ease-of-use, among other characteristics. Decision makers can use the metrics to select amongst alternative automated software testing tools, matching the suite of tools to the needs of a particular software-development project. Experiments were constructed to test the feasibility of generating the test metrics for different versions of a medium-sized software system: one version implemented using a semi-structured procedural design with known faults, and a second version implemented using a well-structured object-oriented design. It was found that we could generate most of the metrics, while other of the metrics would be difficult to compute due to a lack of data or an inability to extract such data about the performance of the tools. Present investigations focus on the validity of the suite of metrics. The investigator is conducting similar research using a larger software testbed, and incorporating additional commercial-off-the-shelf (COTS) tools into the study.

In addition, a rapid prototyping tool was invented, as part of a policy workbench, which automatically tests the logical consistency of policy. A policy workbench supports the rapid prototyping of systems in support of reasoning about policy prior to both committing updates to a policy base and refining policy into requirements and other artifacts of an information system. The approach to testing policy is novel in that test cases and scripts are generated automatically based on the detection of patterns extracted from structural models of policy, which are represented via Unified Modeling Language (UML) class and collaboration diagrams. The automatic classification and detection of patterns is based on temporal, counting, and sequence properties of policies, in addition to the relationships between policy objects. Investigators experimented with our testing-tool component, along with other tools of the policy workbench, using as input to our tools a set of security policies from a well-known published case study.

The investigator served on the Interim Government Advisory Board (GAB), providing oversight and guidance to the federally funded National Institute for Systems Test and Productivity, located at the University of South Florida, Tampa, Fla.

THESIS DIRECTED:

Sezgin, M., "A Pattern-Making Approach for Automated Scenario-Driven Testing of Structured Computational Policy," Masters Thesis, Naval Postgraduate School, September 2001.

Bossuyt, B.J. and Synder, B.B., "Software Testing Tools: Analyses of Effectiveness on Procedural and Object-Oriented Source Code," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Automated Testing, Computer Security, Metrics, Policy Workbench, Software, Test Patterns, Testing Tools

DETECTION OF CHANGES OVER TIME IN LINEAR FEATURES IN AERIAL PHOTOGRAPHS

Neil C. Rowe, Professor
Department of Computer Science
Sponsor: Navy Engineering Logistics Office

OBJECTIVE: A prototype system to find changes between aerial photographs of the same terrain at different times will be developed.

SUMMARY: Work in 2001 extended the earlier work that compared linear features between two photographs of the same terrain taken at different times to find important differences in roads and buildings. The new work compared the regions of the picture to detect differences in irregular and curved areas that cannot be detected by just comparing linear features. This did, however, require more complex matching since regions can have many more features than edge segments. Brightness, brightness variation, narrowness, orientation of the major axes, irregularity of the boundary, as well as comparing the largest straight segments along the boundary was examined. A relaxation process is used to find the best matches between regions of the two pictures: First initial matches are rated, then rerated using local consistency of matches of neighboring regions. The result is a more accurate match between the two pictures as well as one that recognizes differences not found by linear matching.

PUBLICATIONS:

Rowe, N.C. and Grewe, L., "Change Detection for Linear Features in Aerial Photographs Using Edge-Finding," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 39, No. 7, pp. 1608-1612, July/August 2001.

Ingram, D.J., Kremer, H.S. and Rowe, N.C., "Distributed Intrusion Detection for Computer Systems Using Communicating Agents," *Sixth International Symposium on Research and Technology on Command and Control*, June 2001.

Michael, J.B., Ong, V. and Rowe, N.C., "Natural-Language Processing Support for Developing Policy-Governed Software Systems," *39th International Conference on Technology of Object-Oriented Languages and Systems*, Santa Barbara, CA, July-August 2001.

THESES DIRECTED:

Alves, J., "Recognition of Ship Types from an Infrared Image Using Moment Invariants and Neural Networks," Masters Thesis, Naval Postgraduate School, March 2001.

Aragon, A., "Agent-Based Simulation of a Marine Infantry Squad in an Urban Environment," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human-Systems Interface

KEYWORDS: Image Processing, Difference Image, Image Registration Aerial Photography, Terrain Databases

MAGMA: MOBILE CODE APPROACH TO SERVER FAULT TOLERANCE

Geoffrey Xie, Assistant Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: Network middleware support for mobile agent based survivable services is being developed.

SUMMARY: Progress was made in the following areas: general system requirements and specifications, and implementation of a system prototype to demonstrate the feasibility of the proposed approach. One M.S. thesis has been produced as a result.

PUBLICATIONS:

Xie, G.G., *Network Protocols for Building Survivable Services*, Technical Report, NPS-CS-02-004, Department of Computer Science, Naval Postgraduate School, December 2001.

THESIS DIRECTED:

Margulis, S., "MAGMA: A Liquid Software Approach to Fault Tolerance, Computer Security and Survivable Networking," Masters Thesis, Naval Postgraduate School, December 2001.

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

KEYWORDS: Mobile Code, Liquid Software, Fault Tolerance, Survivable Networks

SAAM: NETWORK MANAGEMENT SYSTEM FOR INTEGRATED SERVICES

Geoffrey Xie, Assistant Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: A novel server and agent based active management system for the next generation Internet is being developed.

SUMMARY: Progress was made in the following areas: realistic traffic generation, dynamic bandwidth provisioning, rerouting of real-time flows, survivable SAAM service, best effort traffic engineering, policy-based networking, and application of SAAM concept in underwater acoustic networks.

The SAAM prototype system has been enhanced to incorporate the aforementioned work. Three M.S. theses have been produced as a result.

PUBLICATIONS:

Stone, G., Lundy, G. and Xie, G.G., "Network Policy Languages: A Survey and a New Approach," IEEE Network, Vol. 15, No. 1, pp 10-21, January 2001.

Xie, G.G. and Gibson, J.H., "A Network Layer Protocol for UANs to Address Propagation Delay Induced Performance Limitations," *Proceedings of MTS/IEEE Oceans 2001 Conference*, pp 2087-2094, Honolulu, HI, November 2001.

PRESENTATION:

Xie, G.G. and Gibson, J.H., "A Network Layer Protocol for UANs to Address Propagation Delay induced Performance Limitations," MTS/IEEE Oceans 2001 Conference, Honolulu, HI, November 2001.

THESES DIRECTED:

Turksoyu, F., "Realistic Traffic Generation Capability for SAAM Testbed," Masters Thesis, Naval Postgraduate School, March 2001.

Wright, T., "Fault Tolerance in the Server and Agent-based Network Management (SAAM) System," Masters Thesis, Naval Postgraduate School, September 2001.

Silva, P., "Advanced Quality of Service Management for Next Generation Internet, " Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software, Command, Control and Communications

KEYWORDS: Network Management, Integrated Services, Asynchronous Transfer Mode (ATM), Quality of Service (QoS), Policy Based Networking, Network Security

CONTEXT MACHINE - A DEVICE TO DETERMINE CONTEXT FROM SYMBOLIC INPUTS

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
Perry McDowell, Lecturer
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The purpose of the Augmented Cognition program is to increase the information management capacity of the human-computer warfighting integral by developing and demonstrating quantifiable enhancements to human cognitive ability in diverse, stressful, operational environments of the U.S. warfighter by several orders of magnitude.

SUMMARY: The MOVES Institute at the Naval Postgraduate School is participating in the DARPA Augmented Cognition Program by creating the Context Machine to explore the notion of "context" in a general way, and to study how such a device might improve future warfighting capabilities. The user's current situation, such as their location, their objectives, and the presence of other people and objects, are inputs to the Context Machine. The machine uses the information to determine context. Based upon this context, it determines the best course of action to achieve the user's goals, which is then conveyed to the user. It is imperative that the assistance supplied by the Context Machine be appropriate to the situation, useful, and wanted.

The first step in this research was to identify those situations in which the Context Machine would prove most useful. Those situations are found when the user:

- Cannot understand information in the environment
- Cannot perceive certain information in the environment
- Does not have time to process information in the environment
- Can process the environment, but does not have time to communicate what has been processed.

The second step was to build a software platform for investigation into varying definitions of perception and cognition. A commercial game engine was selected, because of its ready availability from another project, its broad functionality, the ease with which it can be modified, and its reliance on commercial off-the-shelf hardware and software.

A software prototype was successfully constructed, in which the Context Machine aids an infantryman on a clandestine reconnaissance mission. This demonstration was presented to the DARPA sponsor, as well as to numerous distinguished visitors to the Naval Postgraduate School.

As a result of these efforts, the project has been funded for an additional three years.

PUBLICATIONS:

McDowell, P., "A Taxonomy of Context Based Computing," (Paper in progress)

PRESENTATIONS:

Zyda, M., "Interest Management," Workshop on Perceptive User Interfaces, Orlando, FL, 15 November 2001.

THESIS DIRECTED:

McDowell, P., "The Context Machine: A Device to Determine User's Context from Incomplete Data," Ph.D. Dissertation, Naval Postgraduate School, (in progress)

DoD KEY TECH AREAS: Battlespace Environments, Command, Control, and Communications, Computing and Software, Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual Reality, Augmented Cognition, Perception Modeling, Augmented Reality

DEPARTMENT OF COMPUTER SCIENCE

2001
Faculty Publications and Presentations

JOURNAL PAPERS

Capps, M., McDowell, P. and Zyda, M., "A Future for Entertainment-Defense Research Collaboration," *IEEE Computer Graphics and Applications*, pp. 37-43, January/February 2001.

Greiner, R., Darken, C. and Santoso, N.I., "Efficient Reasoning," *ACM Computing Surveys*, Vol. 33, No. 1, pp. 1-30, March 2001.

Darken, R.P. and Peterson, B., "Spatial Orientation, Wayfinding, and Representation," *Handbook of Virtual Environment Technology*, Stanney, K. Ed., 2001.

Morse, K. and Zyda, M., "Multicast Grouping for Data Distribution Management," *SIMPRA - Journal of Simulation Practice and Theory*, Fall 2001.

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Stone, G.N., Lundy, B. and Xie, G.G., "Network Policy Languages: A Survey and a New Approach," *IEEE Networks*, Vol. 15, No. 1, pp. 10 -21, January-February 2001.

Yun, X.P., Bachmann, E.R., Suat, A., Akyol, K. and McGhee, R.B., "An Inertial Navigation System for Small Autonomous Underwater Vehicles," *Advanced Robotics*, Vol. 15, No. 5, pp. 521–532, October 2001.

CONFERENCE PAPERS

Auguston, M., "Visual Meta-Programming Notation," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, pp. 123-129, Monterey, CA, 19-21 June 2001.

Auguston, M., Berzins, V., Bryant, B., Ge, J., Kin, B., Luqi and Shing, M., "DCAPS - Architecture for Distributed Computer Aided Prototyping System," *Proceedings of 12th IEEE International Workshop on Rapid System Prototyping (RSP2001)*, IEEE Computer Society Press 2001, pp. 103-109, Monterey, CA, 25-27 June 2001.

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Bachmann, E.R., McGhee, R.B., Yun, X.P. and Zyda, M.J., "Inertial and Magnetic Posture Tracking for Inserting Humans Into Networked Virtual Reality Systems," *ACM Symposium on Virtual Reality and Software Technology*, November 2001.

Berzins, V., Cheng, K., Harn, M., Luqi and Song, Y., "A Virtual Team on Real-time Embedded Software Development," *Proceedings of the (CCRTS01) Command and Control Research and Technology Symposium 2001*, Annapolis, MD, 19-21 June 2001.

Berzins, V., Auguston, M. and Luqi, "Generating Test Cases for System Generators," *Proceedings of the Conference on Dynamic and Complex System Architecture*, Brisbane, Australia, December 2001.

Berzins, V., Cheng, K., Harn, M., Luqi and Song, Y., "A Virtual Team on Real-Time Embedded Software Development," *Proceedings Command & Control Research & Technology Symposium 2001 (CCRTS01)*, U.S. Naval Academy, Annapolis, MD, 19-21 June 2001.

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Chaki, N., "Engineering Automation for Software Intensive System Integration," *Proceedings of the 8th Monterey Workshop*, Monterey, CA, 19-21 June 2001.

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Choudhury, S., Chaki, N. and Dasgupta, N., "GOOM: A Graph Object Oriented Database Model," *IASTED International Conference PDPTA*, Las Vegas, NV, 25-28 June 2001.

Clark, P., "Supporting the Education of Information Assurance with a Laboratory Environment," *Proceedings of the 5th National Colloquium for Information Systems Security Education*, May 2001.

Darken, R., Kempster, K. and Peterson, B., "Effects of Streaming Video Quality of Service on Spatial Comprehension in a Reconnaissance Task," *Proceedings of I/ITSEC*, Orlando, FL, 2001.

Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," *Proceedings of 14th International Conference on Parallel and Distributed Computing Systems*, pp. 136-141, Dallas, TX, 8-10 August 2001.

Ingram, D., Kremer, H. and Rowe, N., "Distributed Intrusion Detection for Computer Systems Using Communicating Agents," *Sixth International Symposium on Research and Technology on Command and Control*, Annapolis, MD, June 2001.

Irvine, C.E., Levin, T., Wilson, J.D., Shifflett, D. and Pereira, B., "A Case Study in Security Requirements Engineering for a High Assurance System," *Proceedings of the 1st Symposium on Requirements Engineering for Information Security*, Purdue University, Indianapolis, IN, 5-6 March 2001.

Irvine, C.E. and Levin, T., "Data Integrity Limitations in Highly Secure Systems," *Proceedings of the International Systems Security Engineering Conference*, February 2001.

Irvine, C., Levin, T. and Sypropoulou, E., "Security as a Dimension of Quality of Service in Active Service Environments," *Proceedings of the International Workshop on Active Middleware Services*, San Francisco, CA, 6 August 2001.

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Kim, J.K., Kidd, T., Siegel, H.J., Irvine, C., Levin, T., Hensgen, D.A., St. John, D., Prasanna, V.K., Freund, R.F. and Porter, N.W., "Collective Value QoS: A Performance Measure Framework for Distributed Heterogeneous Networks," *Proceedings of the 15th International Parallel and Distributed Processing Symposium*, pp. 810-823, 2001.

Kiselyov, O., "Subclassing Errors, OOP, and Practically Checkable Rules to Prevent Them," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

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Marins, J.L., "An Extended Kalman Filter for Quaternion-Based Orientation Estimation Using MARG Sensors," *Proceedings of 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 2003–2011, Maui, HI, 29 October–3 November 2001.

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Michael, J.B., Ong, V. and Rowe, N.C., "Natural-Language Processing Support for Developing Policy-Governed Software Systems," *39th International Conference on Technology of Object-Oriented Languages and Systems*, Santa Barbara, CA, July-August 2001.

Murrah, M., Johnson, C. and Luqi, "Enhancements & Extensions of Formal Models for Risk Assessment in Software Projects," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

Peterson, B., Boswell, J. and Darken, R., "Collaborative Navigation in Real and Virtual Environments," *Proceedings of I/ITSEC*, Orlando, FL, 2001.

Raje, R., Auguston, M., Bryant, B., Olson, A. and Burt, C., "A Unified Approach for the Integration of Distributed Heterogeneous Software Components," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, pp. 109-119, Monterey, CA, 19-21 June 2001.

Ray, W. and Berzins, V., "Optimization of Distributed Object-Oriented Servers," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration,* Monterey, CA, 19-21 June 2001.

Saboe, M. and Luqi, "A Software Technology Transition Engine," *Proceedings of the 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration*, Monterey, CA, 19-21 June 2001.

Xie, G.G. and Gibson, J.H., "A Network Layer Protocol for UANs to Address Propagation Delay Induced Performance Limitations," *OCEANS 2001 MTS/IEEE Conference*, Vol. 4, pp. 2087–2094, Honolulu, HI, November 2001.

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CONFERENCE PRESENTATIONS

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Berzins, V., Auguston, M. and Luqi, "Generating Test Cases for System Generators," Conference on Dynamic and Complex System Architecture, Brisbane, Australia, December 2001.

Berzins, V., Cheng, K., Harn, M., Luqi and Song, Y., "A Virtual Team on Real-Time Embedded Software Development," Command & Control Research & Technology Symposium 2001 (CCRTS01), U.S. Naval Academy, Annapolis, MD, 19-21 June 2001.

Berzins, V., Luqi and Shing, M., "The Use of Computer-Aided Prototyping for Reengineering Legacy Software," 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration, Monterey, CA, 18-22 June 2001.

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Ge, J., Kin, B. and Berzins, V., "A Software Agent Framework for Distributed Applications," 14th International Conference on Parallel and Distributed Computing Systems, Dallas, TX, 8-10 August 2001.

Irvine, C.E. and Levin, T., "A Cautionary Note Regarding the Data Integrity Capacity of Certain Secure Systems," Fourth International IFIP Working Conference on Integrity and Internal Control in Information Systems, Brussels, Belgium, 15-16 November 2001.

Luqi and Saboe, M., "A Software Technology Transition Engine," 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration, Monterey, CA, 18-22 June 2001.

Luqi, "SEAC & Software Engineering Advisory Board Session with SE Faculty and Ph.D. Students," 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration, Monterey, CA, 18-22 June 2001.

Johnson, C., Murrah, M. and Luqi, "Software Project Risk Management," 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration, Monterey, CA, 18-22 June 2001.

Ray, W. and Berzins, V., "Optimization of Distributed Object-Oriented Servers," 8th Monterey Workshop: Engineering Automation for Software Intensive System Integration, Monterey, CA, 18-22 June 2001.

Shing, M., Jackson, L. and Chalakatevakis, A., "Architectural Design and Prototyping of a Web-Based War Game Simulation for Campaign Planning Exercises," 13th Annual Software Technology Conference, Salt Lake City, UT, 29 April-3 May 2001.

Xie, G.G. and Gibson, J.H., "A Network Layer Protocol for UANs to Address Propagation Delay Induced Performance Limitations," MTS/IEEE Oceans 2001 Conference, Honolulu, HI, November 2001.

Zyda, M., "Interest Management," Workshop on Perceptive User Interfaces, Orlando, FL, 15 November 2001.

Zyda, M., "The Future of Modeling, Virtual Environments and Simulation," IITSEC 2001, Orlando, FL, 29 November 2001.

Zyda, M., Tutorial on "The Future of Interactive Networked Entertainment," IITSEC 2001, Orlando, FL, 26 November 2001.

Zyda, M., "Interest Management," Workshop on Perceptive User Interfaces, Orlando, FL, 15 November 2001.

Zyda, M., Panel on "The Future of Interactive Networked Entertainment," VSMM Conference, Berkeley, CA, 27 October 2001.

Zyda, M., "The MOVES Institute" and "The Future of Modeling, Virtual Environments and Simulation," Summer Computer Simulation Conference, Orlando, FL, 16-18 July 2001.

TECHNICAL REPORTS

Berzins, V., *XML Technology Assessment*, Naval Postgraduate School Technical Report, NPS-SW-01-002, January 2001.

Luqi, *Master of Science in Software Engineering Academic Program Manual*, Naval Postgraduate School Technical Report, NPS-SW-01-001, July 2001.

Luqi, *System Engineering and Evolution Decision Support*, Naval Postgraduate School Technical Report, NPS-SW-01-003, September 2001.

Luqi, *Engineering Automation for Reliable Software*, Naval Postgraduate School Technical Report, NPS-SW-01-004, September 2001.

Luqi and Sheehan, J., *Assessment of DMSO Conceptual Models of the Mission Space*, Naval Postgraduate School Technical Report, NPS-SW-01-005, January 2001.

Xie, G.G., *Network Protocols for Building Survivable Services*, Naval Postgraduate School Technical Report, NPS-CS-02-004, December 2001.

OTHER

Kiselyov, O., "Distributing Weather Products through an HTTP Pipe," 1 February 2001, http://zowie.metnet.navy.mil/~spawar/JMV-TNG/.

Bachmann, E., McGhee, R., McKinney, D., Yun, X. and Zyda, M., "Method and Apparatus for Motion Tracking of an Articulated Rigid Body," Provisional Patent filed October 1999, Final Patent filed 30 October 2001.

Michael, J.B., Auguston, M., Rowe, N.C. and Riehle, R.D., "Information Warfare Seminar Series," Naval Information Warfare Activity, Washington, D.C., Institute for Defense Analyses, Alexandria, VA, George Mason University, Fairfax, VA and Naval Postgraduate School, Monterey, CA.

DEPARTMENT OF DEFENSE ANALYSIS

GORDON MCCORMICK
CHAIR

DEFENSE ANALYSIS

OVERVIEW:

The Department of Defense Analysis is an interdisciplinary program, drawing on a wide range of academic specialties. The program provides a focused course of instruction on the dynamics of asymmetric warfare, sub-state conflict, terrorism, information operations, and other "high leverage" operations in U.S. defense and foreign policy. The core program also provides every student with a strong background in strategic analysis, international relations and comparative politics, organization theory, and formal analytical methods.

CURRICULUM SERVED:

- Special Operations

DEGREE GRANTED:

- Master of Science in Defense Analysis

RESEARCH THRUSTS:

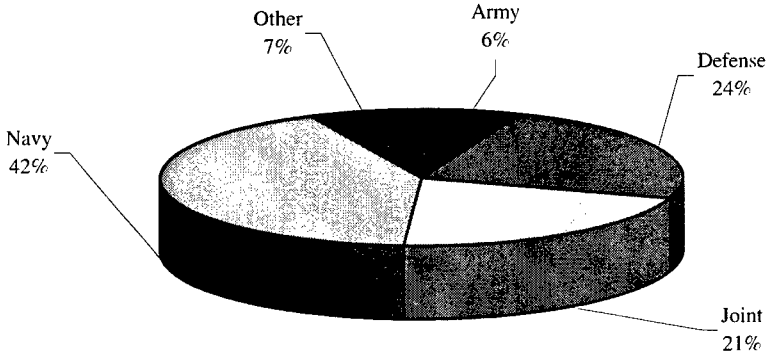
- Special Operations
- Asymmetric Warfare
- Sub-State Conflict
- Terrorism
- Information Operations
- Defense and Foreign Policy

RESEARCH CENTERS:

- Center on Terrorism and Irregular Warfare

SPONSORED PROGRAM (Research and Academic)-FY2001:

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



Size of Program: $701K

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DETERING REGIONAL AGRESSION

John Arquilla, Associate Professor
Gordon McCormick, Associate Professor
Department of Defense Analysis
Sponsor: U.S. Army Office of Operations and Plans

OBJECTIVE: To determine and analyze the trends emerging in international security at the regional level, including identification of potential adversaries and assessment of their technological capabilities.

SUMMARY: Throughout history great powers have had to wrestle with the problem of maintaining their influence over the world around them. Often these powers were simultaneously faced with more than one opponent. In order to meet multiple challenges, leading nations have had to maximize the number of potential adversaries they could influence with each action or policy. Those faced with this dilemma have included the Romans, Byzantines, and the British Empire. Studying these nations in their struggle to maintain control revealed tactics and techniques that proved effective. Forward deployment, statements of perseverance, the use of coalitions, strategic distraction of opponents, and the demonstration of their relative superiority over adversaries all helped to preserve the longevity of these empires. Additionally, an effective information campaign, which amplified successes, proved invaluable to these world powers.

THESIS DIRECTED:

Palmer, J., Stebbins, M. and Zacherl, A., "The Gunfighter's Dilemma: Multiple Adversary Deterrence and Coercion," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Other (International Security)

KEYWORDS: International Security, Economic Analysis

RESEARCH AND ANALYSIS OF TERRORIST INFORMATION OPERATIONS (RATIO): INFORMATION OPERATIONS CASE LITERATURE

John Arquilla, Associate Professor
David Tucker, Associate Professor
Department of Defense Analysis
Sponsors: Defense Intelligence Agency and Joint Special Operations Command

OBJECTIVE: The information revolution has already had profound effects on commerce and military affairs, and may transform or energize terrorism in the coming years. It is thus necessary that those who must defend against or counter acts of terror begin a process of assessing trends in terrorist usage of advanced information technologies, and identifying the ways in which terrorist might employ information operations and computer network attack tools.

SUMMARY: The research produced a series of studies on terrorist use of information technology and a database of tools.

PUBLICATIONS:

Craddock, D. and Palmer, J., "Cyberterror: Prospects and Implications," Naval Postgraduate School Technical Report, NPS-SO-00-01, October 2000.

Tucker, D., "The Future of Armed Resistance: Cyberterror? Mass Destruction?" Naval Postgraduate School Technical Report, NPS-SO-00-02, October 2000.

Zanini, M. and Edwards, S., "The Informatization of Terrorist Groups," Naval Postgraduate School Technical Report, NPS-SO-00-03, October 2000.

Gerwehr, S., Weissler, R., Medby, J., Anderson, R. and Rothenberg, J., "Psyop and Deception in Cyber Conflict," Naval Postgraduate School Technical Report, NPS-SO-00-04, October 2000.

Moore, T., "Subs in the Andes: Rise of an Non-State Navy?" Naval Postgraduate School Technical Report, NPS-SO-01-01, June 2001.

Moore, T., "Winning the Psywar in Colombia," Naval Postgraduate School Technical Report, NPS-SO-01-02, June 2001.

THESES DIRECTED:

Foster, P., Moore, T., and Wheeler, J., "Cyberterrorism: Are We Ready for the Future," Masters Thesis, Naval Postgraduate School, June 2001.

Craddock, D., "Cover in Transition: Information Technologies in Overt, Covert, and Clandestine Activities," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGIES: Other (Terriorism)

KEYWORDS: Cyberterror, Terrorism, Information Warfare, Psychological Operations

SPECIAL OPERATIONS ACADEMIC CURRICULUM

Gordon McCormick, Associate Professor
Department of Defense Analysis
Sponsor: Naval Special Warfare Command

OBJECTIVE: The special operations academic curriculum is an 18 month program supported by the U.S. Special Operations Command.

SUMMARY: The Special Operations Curriculum is designed to provide a focused course of study of the conflict spectrum below general conventional war. Graduates of this curriculum will possess a close knowledge of the broad range of factors involved in the planning and conduct of these forms of conflict and a detailed understanding of the role of special operations and related forces in U.S. foreign and defense policy. The curriculum examines the sources and dynamics of inter-state and intra-state conflict, the challenge these forms of conflict have posed and are likely to increasingly pose for U.S. security planning, the doctrinal and institutional evolution of the U.S. special operations community, the recent history of political violence and "small wars" in Latin America, Asia, and the Middle East, the history of irregular warfare, and contemporary perspectives on low intensity conflict resolution. These curriculum specific requirements are supported by a larger program of study which provides the graduate with a broad background in the areas of international relations, comparative strategy, the technological revolution in military affairs, and advanced analytical methods.

DoD KEY TECHNOLOGY AREAS: Other (Special Operations)

KEYWORDS: Special Operations, Low Intensity Conflict

CAUSES OF MILITARY INNOVATION: CASE STUDIES FROM THE HISTORY OF SPECIAL OPERATIONS FORCES

David Tucker, Associate Professor
Department of Defense Analysis
Sponsor: Smith Richardson Foundation

OBJECTIVE: To develop an understanding of innovation in the military based on examining the post-Word War II history of Special Operations Forces (SOF).

SUMMARY: The research consists of an extensive review of the literature on military innovation and a series of case studies. The literature review culminates with a statement of a proposed model of innovation, which the case studies then test. The case studies are drawn from American, British and French experience.

PRESENTATIONS:

Tucker, D.,"Innovating to Meet Unconventional Threats," presentation at the Bi-annual Meeting of the Inter-University Seminar on the Armed Forces and Society, October 2001.

THESIS DIRECTED:

Rainville, T., "Stimulating Innovation in Naval Special Warfare by Utilizing Small Working Groups," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Other (Special Operations)

KEYWORDS: Special Operations Froces, Innovation

DEPARTMENT OF DEFENSE ANALYSIS

2001
Faculty Publications and Presentations

CONFERENCE PRESENTATIONS

Tucker, D., "Innovating to Meet Unconventional Threats," presentation at the Bi-annual Meeting of the Inter-University Seminar on the Armed Forces and Society, October 2001.

TECHNICAL REPORTS

Craddock, D. and Palmer, J., "Cyberterror: Prospects and Implications," Naval Postgraduate School Technical Report, NPS-SO-00-01, October 2000.

Gerwehr, S., Weissler, R., Medby, J., Anderson, R. and Rothenberg, J., "Psyop and Deception in Cyber Conflict," Naval Postgraduate School Technical Report, NPS-SO-00-04, October 2000.

Moore, T., "Subs in the Andes: Rise of an Non-State Navy?" Naval Postgraduate School Technical Report, NPS-SO-01-01, June 2001.

Moore, T., "Winning the Psywar in Colombia," Naval Postgraduate School Technical Report, NPS-SO-01-02, June 2001.

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Zanini, M. and Edwards, S., "The Informatization of Terrorist Groups," Naval Postgraduate School Technical Report, NPS-SO-00-03, October 2000.

DEPARTMENT OF INFORMATION SCIENCE

DAN BOGER
CHAIR

INFORMATION SCIENCE

OVERVIEW:

The Information Science (IS) Department is an interdisciplinary association of faculty interested in problems associated with defense information systems, command, control and communications, and information warfare/operations.

CURRICULA SERVED:

- Information Systems Technology
- Information Systems and Operations
- Joint Command, Control, Communications, Computers and Intelligence Systems
- Information Systems Technology
- Information Warfare
- Electronic Warfare Systems International

DEGREES GRANTED:

- Master of Science in Information Systems and Operations
- Master of Science in Information Technology Management
- Master of Science in Systems Engineering
- Master of Science in Systems Technology

RESEARCH THRUSTS:

- Software Metrics and Maintenance
- IT Architectures
- Computer Networks
- Decision Support Systems
- Knowledge Management
- Information Warfare
- Information Superiority
- Information Operations
- Command and Control
- Modeling and Analysis of Military Systems
- Combat Identification
- Human Systems Interface
- Threat Analysis

RESEARCH FACILITIES:

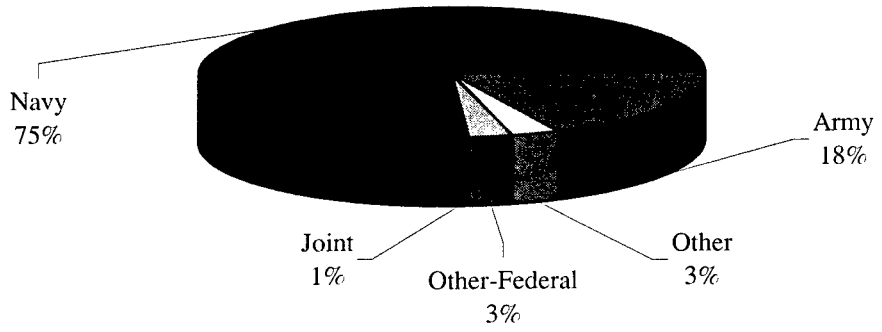
- Systems Technology Laboratories (STL): The Naval Postgraduate School Systems Technology Laboratories provide centrally managed, supported, and funded facilities where students and faculty can conduct research and instruction using tomorrow's C4I systems technologies today. The facilities provide for classified and unclassified capabilities for students and faculty to use for immediate classroom reinforcement, student projects, and theses and for faculty and students to conduct leading edge research in their fields. The labs, through advanced telecommunications and networking, allow local platforms of various types to communicate at very high data rates with each other over the Naval Postgraduate School backbone and with other national laboratories and research facilities worldwide using Internet, SIPRNET, and ATM networks, such as DARPA's Leading Edge Services ATM network, the California Research and Education Net (CALREN), Defense Research and Evaluation Net (DREN), and other wideband wide area networks that define the nation's information infrastructure. Using these capabilities, researchers can

collaborate with leading researchers and can participate in systems technology research efforts of national prominence.

The Naval Postgraduate School Systems Technology Laboratories contain (or have distributed access to) actual command and control systems for exercises and experiments. The prime example of this is a fully functional CINC version of the Global Command and Control Systems (GCCS) with SECRET interconnectivity to all CINCs and supporting sites. GCCS permits CINCs to complete crisis action plans including assessment, evaluation, and development of options, as will as selection, dissemination and monitoring of execution. The STL routinely conducts experiments with humans in the loop. Operational teams of officer-students can be trained/tested-using wargames as stimuli and using data collection techniques to evaluate performance under varied, but controlled, conditions. Insights into requirements for new doctrine, training and other aspects of the joint environment may be identified that will speed the acceptance of new approaches to decision-making and training.

RESEARCH PROGRAM (Research and Academic)-FY2001:

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



Size of Program: $2327K

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ADAPTIVE MANAGEMENT OF WIRELESS C4ISR NETWORKS

Alex Bordetsky, Associate Professor
Department of Information Science
Sponsor: Aprisma Technologies

OBJECTIVE: Explore network management systems capability to identify intrusion detection patterns within the framework of SNMP MIBs analysis in wireless C4I networks

SUMMARY: The NPS team will setup P2P wireless collaborative network testbed with SNMP agents active at each node of the wireless network. The Spectrum systems security management and case-based reasoning agents will be used to identify the SNMP MIB variables most sensitive to the set of denial of service attacks. The results have to be compared with Aprisma findings on managing North Carolina Internet 2 Giga POP and complied in network management knowledge base. Recommendations to Situational Awareness agents providing feedback on network state during the attack will complement the research.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Adaptive Network Management, Wireless Collaborative Networks, C4I Networks, SNMP MIBs, Intrusion Detection, Knowledge-Base, Management Agents, Network-Centric Infrastructures

HUMAN-CENTRIC DESIGN OF COLLABORATOR/AGENT INTERFACES

Alex Bordetsky, Associate Professor
Department of Information Science
Sponsor: Space and Naval Warfare Systems Center – San Diego

OBJECTIVE: Explore the decision support requirements to collaborative technology/agent interfaces for multinational peace keeping and humanitarian operations. Develop the plan and detailed proposal for the following on study of adaptive collaboration interfaces for decision-making in multinational experiments.

SUMMARY: The Naval Postgraduate Team will use the results of current Joint Interactive Planning/Rapid Decisive Operation studies of effective collaboration for multinational peacekeeping and humanitarian operations. The findings of committee, team, and group collaborative architectures decision support requirements, cognitive styles, and cultural barriers of collaborators will be used to address the issues of collaborator/agent interfaces experimental studies. Visual collaborative interfaces, multiple agent platform, and case-based reasoning knowledge management facility at NPS will be used to explore specific requirements to the adaptive human-agent interfaces. The study will result in the proposal the proof-of-concept multinational experiments. In addition to the detailed plan of experiments for exploring adaptive human-agent interfaces the proposal will also address design and implementation of multinational conflict resolution collaborative testbed with Swedish National Defense College.

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

KEYWORDS: Collaborative Interfaces, Multiagent System, Case-Based Reasoning, Knowledge Management, Multinational Experiments, Collaborative Technology, Network-Centric Decision Support

FEEDBACK MECHANISMS FOR AGENT-BASED QOS ADAPTIVE MANAGEMENT OF NETWORKING RESOURCES

Alex Bordetsky, Associate Professor
Department of Information Science
Sponsor: SBC Research Labs

OBJECTIVE: The goal for proposed research is to develop better understanding of how the behavior of two main types of networking nodes, the edge nodes and tandem nodes, could be improved based on the presence of intelligent agents at different observation points within the network. The specific research task is to identify the feedback mechanisms capable of utilizing information gathered by intelligent agents for optimizing network resources usage. The study should focus on the experimental research based on testing and proof-of-concept experiments. The research should provide an experimental background for addressing the problems of networking resources adaptation in Quality of Service Management.

SUMMARY: The project will be conducted in two phases: The project work in phase 1 will be focused on exploring the effects of individual intelligent agents on the usage of edge and tandem node resources. The problems and ways of agents-facilitators communication with SNMP agents and SNMP agents manager will be explored. Effects of agents allocation (concentration) within the network, and usage patterns of agents shared memory will also be investigated.

The second phase will be focused on the effects of intelligent agents cooperation for optimizing the usage of networking resources. How the agents performance and memory responsiveness affect the agents solution on resource reservation along the lines of Call Setup and Connection Control adaptation cycles will be observed. Implementation of how ANN could improve the agents performance in adaptation of networking resources will be explored.

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

KEYWORDS: Network Operations Management, Intelligent Agents, Adaptation, Feedback, Agents Memory

INTEROPERABILITY, ARCHITECTURE, AND PLANNING SUPPORT TO SSC CHARLESTON

Rex Buddenberg, Senior Lecturer
Department of Information Science
Sponsor: Space and Naval Warfare Systems Center

OBJECTIVE: To provide support for the fleet NOC and related projects.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: IT Architecture

CNSG COMPUTER NETWORK DEFENSE INITIATIVE

LCDR Raymond Buettner, USN, Military Faculty
Department of Information Science
Sponsor: Naval Security Group Command

OBJECTIVE: Examine and develop new process for supporting computer network defense (CND) efforts of the U.S. Navy. Identify, evaluate and make implementation recommendations for new CND tactics and mechanisms. This effort will primarily focus on pattern less intrusion detection (PID), external threat assessment (ETA) warning mechanisms and the development of a firewall assessment modeling methodology but may include other efforts as identified by the principal investigator.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Information Operations, Information Warfare, Modeling and Simulation, Computer Network Defense

INFORMATION OPERATIONS MODELING AND SIMULATION

LCDR Raymond Buettner, USN, Military Faculty
Department of Information Science
Sponsor: Office of Naval Research

OBJECTIVE: Examine current modeling and simulation efforts to determine tools that may be useful to the IO/IW community. Analyze suitable modeling and simulation tools to determine those which warrant continued study. For selected applications, develop recommendations and modifications to permit evaluation for use by information warriors. Simultaneously identify models that can increase the quality of IO education either through classroom use or thesis research opportunities.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Information Operations, Information Warfare, Modeling and Simulation, Influence Modeling, Reflexive Modeling

INTERNET OPERATIONS PROJECT

LCDR Raymond Buettner, USN, Military Faculty
Department of Information Science
Sponsor: Joint Information Operations Center

OBJECTIVE: Examine and develop processes for developing and applying specialized web sites to existing operational needs as defined by joint and Navy regional and combat CINCs. Identify information operations tactics and procedures to optimize effectiveness of these web sites for full spectrum IO across the range of peace-crisis-conflict.

DoD KEY TECHNOLOGY AREAS: Other (Information Operations)

KEYWORDS: Information Operations, Information Warfare, Modeling and Simulation

GUN WEAPONS SYSTEM COMMAND AND CONTROL PROJECT

Alexander Callahan, Research Assistant Professor
Department of Information Science
Sponsor: Naval Surface Warfare Center – Crane Division

OBJECTIVE: Provide gun weapon system analysis of performance and command and control to include consulting, modeling and simulation.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Analysis, Modeling and Simulation

NAVAL SIMULATION SYSTEM (NSS) DEVELOPMENT AND TESTING

Alexander Callahan, Research Assistant Professor
Department of Information Science
Sponsor: Commander in Chief, Pacific Fleet

OBJECTIVE: To provide development of scenarios and operational testing of the Naval Simulation System. Scope includes planning, modeling, simulation and analysis.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Analysis, Modeling, Simulation

NAVAL SURFACE SUPPORT FOR JOINT LAND WARRIOR STUDY

Alexander Callahan, Research Assistant Professor
Department of Information Science
Sponsor: Naval Surface Warfare Center – Crane Division

OBJECTIVE: This study will provide an analysis of the methodology to evaluate the effective use of Naval surface gunfire support of the joint land warrior in expeditionary maneuver warfare. The scope will include the use of modeling and simulation techniques recently developed for the Naval Simulation System (NSS) and other appropriate analytic systems.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Naval Simulation System, Joint Land Warrior, Expeditionary Maneuver Warfare

USAREC RECRUITING STRATEGIC VISION PROGRAM (RSVP) WARGAME SIMULATION FOR STRATEGIC PLANNING AND DECISION SUPPORT

Daniel R. Dolk, Professor
Department of Information Science
Sponsor: U.S. Army Recruiting Command

OBJECTIVE: The objective is to create and conduct a reusable, multi-player war game simulation for the Army recruiting leadership (RSVP/ARL). The purpose of this simulation is to explore strategic planning dimensions of the recruiting organization in the Army with the specific goal of being able to provide specific guidelines to the officers attending the annual summer leadership meeting at USAREC. This system will not be a prototype but an operational simulation that will be used and updated on an annual basis. The work on this project will lead to a second phase involving development of a detailed recruiting market simulation (RSVP/RMS) that will allow USAREC to test the virtual effectiveness of various new recruiting-oriented products and market strategies. Leveraging the powerful agency technology of SEAS, this simulation will be able to emulate meaningful market segments and provide valuable insight into relevant market behavior. This will facilitate the preliminary identification of "more promising" vs. "less promising" products prior to the expensive activity of national testing.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Agent-Based Simulation, Military Recruiting Policy

USAREC RECRUITING STRATEGIC VISION PROGRAM RECRUITING WARGAME MARKET SIMULATION (RSVP/RMS) WARGAME

Daniel R. Dolk, Professor
Department of Information Science
Sponsor: U.S. Army TRADOC Analysis Command

OBJECTIVE: This is the second phase of the RSVP project for implementing strategic business war-games at USAREC. The objective of this phase is to develop a detailed recruiting market simulation (RSVP/RMS) that will allow USAREC to test the virtual effectiveness of various new recruiting-oriented products and market strategies. Leveraging the powerful agent technology of the SEAS environment, this simulation will be able to emulate meaningful market segments and provide valuable insight into relevant market behavior. This will facilitate the preliminary identification of "more promising" vs. "Less Promising" products prior to the expensive activity of national testing.

SUMMARY: Two major thrusts have occurred in this project: (1) a 2nd version of the strategic war game simulation (SWGS) to be presented in September 2002, and (2) an operational decision support system (ODSS) for the CG of USAREC. The user interface for the ODSS and for presenting results of the SWGS are identical. This allows a seamless transition from viewing data about real world operations, as contained in the USAREC data warehouse, and viewing data from simulations that implement various recruiting policies and decisions specified by the war game players.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Modeling and Simulation, Human Systems Interface

KEYWORDS: Agent-Based Simulations, OLAP, Military Recruiting Policy

DEVELOPMENT OF THE HCDA FOR THE MANNING AFFORDABILITY PROJECT

Sue Hutchins, Research Associate Professor
Department of Information Science
Sponsor: Naval Air Warfare Center - Training Systems Division

OBJECTIVE: The focus of this year's effort will be collecting additional case studies to illustrate potential system design problems and working with the HCDA design team to translate the case studies to a format that will be useful for incorporation into the HCDA. The case studies are to represent the range of design problems found in complex military command and control systems and the ways in which these types of problems can be avoided in future system design.

SUMMARY: The overall purpose of this effort is to support the development of the Human-Centered Design Associate (HCDA), an intelligent software agent designed to provide human factors knowledge and expertise to a system designer. In particular, there are three tasks. The first task is to provide human factors case studies of system design to populate the database of the intelligent search agent component of the HCDA. The second task is to provide guidance in the search for additional high payoff areas within the system design process that can be supported with HCDA components. The third task is to support the testing and evaluation of each component of the HCDA.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface

KEYWORDS: Human Factors, Automation, Decision Theory/Support System, Command and Control, Human-System Interface

COMMANDING AND CONTROLLING 21st CENTURY MILITARY FORCES: THE COMMAND AND CONTROL – EMERGING EFFECTS FRAMEWORK

Erik Jansen, Senior Lecturer
Carl R. Jones, Professor
Michael G. Sovereign, Professor Emeritus
Department of Information Science
Sponsor: Unfunded

OBJECTIVE: Develop an analytical framework to describe, design, operate, and adapt military forces for mission success in a 21st century ecology of conflict and cooperation.

SUMMARY: The Command and Control – Emerging Effects (C2E2) framework is comprised of concepts for (1) organizing the force in terms of a problem-focused logic, (2) embedding the organized logic in a physically realizable force architecture with specifications for manpower and technical systems, (3) understanding the executable force as a resourced force architecture comprised of control – coordination processes and a command process observed as a dialogue involving interpreting, assessing, deciding, leading, and collaborating, and (4) the executing operational force. The force's evolution is an element of the evolution of the ecology of conflict and cooperation with emerging effects among friends, foes, and neutrals. The C2E2 framework can be used to understand such phenomena as force vulnerability, adaptation, self-organizing, self-synchronization, knowledge and information engineering and management, network centric warfare, and effects-based warfare.

DoD KEY TECHNICAL AREAS: Battlespace Environments, Command, Control, and Communication, Modeling and Simulation

KEYWORDS: Command, Control, Command and Control, Joint Technical Architecture, C4ISR Systems, Organizational Sciences, Management, Leadership, Ecological Evolution, Complex Adaptive Systems

DEVELOPMENT OF AN ADVANCED PROOF-OF-CONCEPT WORLD WIDE WEB PROTOTYPE APPLICATION FOR ONLINE RECRUITING

Magdi N. Kamel, Associate Professor
Department of Information Science
Sponsor: U.S. Military Entrance Processing Command

OBJECTIVE: The objective of this research is to develop an advanced proof-of-concept world wide web prototype application to support prospecting, attracting, screening, closing the sale, and processing of new Navy recruits.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Application and Development, World Wide Web, Internet, E-Commerce, Military Recruiting

DEVELOPMENT OF A REPEATABLE EDUCATION AND TRAINING NEEDS ASSESMENT PROCESS FOR SPAWAR INFORMATION TECHNOLOGY

Magdi N. Kamel, Associate Professor
Department of Information Science
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this research is to develop a repeatable education and training needs assessment process for the ITC workforce.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Needs Assessment, Requirements Identification, Education, Training

ADAPTIVE ARCHITECTURES FOR COMMAND AND CONTROL (A2C2)

William Kemple, Associate Professor
Department of Information Science
Sponsor: Office of Naval Research

OBJECTIVE: To investigate adaptation in joint C2 architectures and to develop theories of C2, i.e., "Congruence" of task organization. To use modeling to identify near-optimal organizational decisions for C2 tasks. Other goals include testing the theories and models in a series of experiments and supporting implementation of adaptable C2 architectures.

SUMMARY: The Adaptive Architectures for Command and Control (A2C2) research project is a multi-year program of basic and applied research featuring model-based experimentation and including "outreach" to DoD/DoN operational, experimental and concept development activities. The program is a collaborative effort involving industry, university and government researchers. Program goals include: 1) extending 14+ years of naval composite warfare decision-making research into the Joint Command and Control (C2) arena; 2) focusing on adaptive architectures within decision-making organizations; and 3) producing results that range from the purely theoretical to those that can be used by operational forces. The prototype A2C2 experiment design combines an operational scenario, computer-based architecture models and model-based predictions of the performance of those architectures on the operational scenario. The experiment tests these architectures in a series of human-in-the-loop experiments using military officers operating in a Joint setting as the test subjects and also provides feedback to the models.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface

KEYWORDS: Command and Control, Joint Operations, Organizational Experiments

NAVAL POSTGRADUATE SCHOOL EFFORT TO SUPPORT GLOBAL WARGAME 2001

William Kemple, Associate Professor
Sue Hutchins, Research Associate Professor
Department of Information Science
Sponsor: Office of Naval Research

OBJECTIVE: NPS support for global wargame 2001 will consist of two components: The first component involves direct support to advancing A2C2 research; the second involves providing support to the joint force command J9 effort.

SUMMARY: New warfighting concepts are currently under development at U.S. Joint Forces Command (JFCOM), J9, Joint Experimentation Directorate, to support the U.S. military as it transitions to the Fighting Force described in Joint Vision 2020. Joint Vision 2020 stresses the need for achieving full spectrum dominance, where forces support the military capability to perform missions from peacekeeping to conflict deterrence prevention to fighting and winning against fully capable enemies. This is to be accomplished by using the latest advances in computer technology, information superiority, improved jointness, precision operations, dominant maneuver, focused logistics, and full-dimension protection. Implementation of these new concepts will occur via new ways of organizing the Joint Force, new processes, and the use of tools and advanced technology to support their implementation.

Future operations will be characterized by unique, one-of-a-kind actions, with changing/ diverse partners, based on uncertain data and requiring quick response on high-impact issues. Characteristics of this new environment include: operations with joint, coalition, non-government, and volunteer organization partners; a shift from extended engagement with a single opponent to local discrete events; dealing with open-source (uncertain, conflicting, partial, non-official) data; rapidly changing team members

and associated organizational structures; culturally diverse partners; and short turn-around, high stakes, politically charged decision making. A series of experiments and exercises is being conducted to help refine the new concepts and processes under development at JFCOM. Each experiment is designed to support assessments of future capabilities and modification of current doctrine, organization, materiel, leadership, and procedures.

DoD KEY TECHNOLOGY AREAS: Other (Information Technology)

KEYWORDS: Network-Centric Operations, Operational Decision Making, Knowledge Wall

ADVANCED COMMAND AND CONTROL (AC2) RESEARCH SUPPORT

William Kemple, Associate Professor
Department of Information Science
Susan Hocevar, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Chief of Naval Operations (N6)

OBJECTIVE: The purpose of this research is to advance our understanding of the implications of network centric operations to command and control. This will be accomplished through an integrated experiment process that links advanced concept seminar-type wargames with simulation-based wargame experiments, OPNAV N6 has identified particular areas of interest to include: Highlight risks and opportunities for C2, explore unintended consequences, identify guiding principals (i.e., Rules, models, metrics), clarify and articulate assumptions and relevant uncertainties.

SUMMARY: Modified human decision-making processes are required—in addition to new tactics and technology that are also currently under development—to enable Joint military forces to operate in a time span that is shorter than an adversary's. Self-synchronization is viewed as an essential process within military organizations that can increase speed of command and thus accelerate execution of the mission. This process of self-synchronization is described as the ability of a well-informed force to organize and synchronize complex warfare activities from the bottom up. The organizing principles are unity of effort, clearly articulated commander's intent, and carefully crafted rules of engagement. Self-synchronization is viewed as a mechanism to overcome the loss of combat power inherent in top-down, command-directed coordination that is characteristic of conventional command and control doctrine. One enabler of self-synchronization is a high level of knowledge of one's own forces, enemy forces, and all appropriate elements of the operating environment. This new style of coordination offers the potential to convert combat from a step function to a high-speed continuum.

An experiment in support of CNO N6C's Advanced Command and Control (AC2) Study was conducted. The objective of the AC2 study is to investigate the nature of command and control as the US Navy evolves toward a network-centric concept of future maritime operations. The focus of the experiment was the conditions (or "enablers") that promote decisionmakers' ability to self-synchronize their efforts. This concept of self-synchronization was examined within the context of a task force responding to time-critical strike and theater air-missile defense missions. An innovative "hybrid" approach that combined concept development seminar games with an experiment process composed of integrated activities, tools, and methods that capitalize on the NPS research team's capabilities, was used to support an area requiring investigation by OPNAV, N6C. A multi-disciplinary approach, including seminar games, models and simulations, interviews, surveys, and other knowledge capture method, matches these methodologies to the requirements of the AC2 study.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communication

KEYWORDS: Command and Control, Modeling and Simulation

RED CELL ANALYSIS OF DISRUPTIVE TECHNOLOGIES IDENTIFICATION OF POTENTIAL ADVERSARY SYSTEMS AND TECHNOLOGIES TO DISRUPT U.S. NAVAL OPERATIONS

John S. Osmundson, Associate Professor
D. C. Schleher, Professor
Department of Information Science
Robert C. Harney, Senior Lecturer
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Naval Warfare Development Command

OBJECTIVE: Assess disruptive technologies that might be employed in the 2015 time frame to deny access to the U.S. Navy. Compare the list of disruptive technologies to and reconcile with U.S. intelligence agencies' assessments.

SUMMARY: This study was directed at identifying and analyzing commercial-off-the-shelf and readily available technologies that might be available to a U.S. adversary in the 2007 to 20015 timeframe to use in a disruptive manner in an anti-access role against U.S. Naval forces. Five dimensions of battlespace were considered: Surface (land and sea), subsurface (land and sea), air, space and cyberspace. Estimates were made of the probability of employment of each of the systems and technologies based on maturity of the systems and technologies, probable costs and development schedules and any other relevant factors. Previous Naval Postgraduate School student area denial study results, published lists of critical technologies, and brainstorming by Naval Postgraduate faculty and systems engineering integration (SEI) students were used as inputs to this study. The approach taken was to encourage "thinking out of the box" rather than relying on observed evidences of potential threats.

Systems and technologies were evaluated in terms of their impact on U.S. forces in an anti-access mode and their probability of occurring. Systems ranked high in both impact and probability of occurrence were analyzed further, where appropriate, to determine estimates of system parameters. Twenty four systems, technologies and attack mechanisms were determined to be high risk to U.S. naval forces. Sixteen systems, technologies and attack mechanisms were found to be medium risk.

PUBLICATIONS:

Osmundsen, J.S, Schleher, D.C. and Harney, R.C., *Identification of Potential Adversary Systems and Technologies to Disrupt US Naval Operations, ANTI-ACCESS SYSTEMS STUDY*, Naval Postgraduate School Technical Report, NPS-JW-01-015, 31 January 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles, Battlespace Environments, Computing and Software, Conventional Weapons, Electronic Warfare, Directed Energy Weapons, Sensors, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Red Cell Analysis, Disruptive Technologies

DETECTION OF LPI RADAR SIGNALS

D. C. Schleher, Professor
Department of Information Science
Sponsor: National Reconnaissance Office

OBJECTIVE: To design and synthesize an ELINT receiver capable of detecting LPI radar signals with the same sensitivity as available on equivalent conventional pulsed signals. To accomplish this detection in the presence of a large number of interfering conventional pulsed radars and to measure the radar's mode, allowing the operating range of the LPI radar to be determined.

SUMMARY: An adaptive LPI Radar Detector has been synthesized and successfully simulated. As determined by simulation, it provides an operationally significant range of 60 km on a known LPI radar signal. In addition, it determines the LPI radar's mode. A temporal mask approach is used to allow

detection of the LPI radar signal in the presence of over 500 Furono radars with random modes. An experimental demonstration was successfully conducted that confirmed the theoretical design. The experiment used a threat simulator that radiated synthesized LPI radar signals. The LPI signals were intercepted by a Low Noise Receiver and A/D converter using a 250 MHz Gage Digital Sampling Oscilloscope. The signal was then processed in a digital signal processor using MATLAB code. LPI signals at a level of -108 to -120 dBm were detected and the radar's mode determined.

THESIS DIRECTED:

Teng, H. and Ong, P., "Digital LPI Radar Detector," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Command, Control and Communication

KEYWORDS: SIGINT, LPI Radar, Digital Pulse Compression, Surveillance

JAMMING TACTICS AND EMPLOYMENT OF UEU AGAINST ADVANCED RADAR AND COMMUNICATIONS SYSTEMS

D. C. Schleher, Professor
Department of Information Science
Sponsor: Navy Information Warfare Activity

OBJECTIVE: Develop UEU employment tactics and advanced jamming techniques to counter communications, data links and advanced J-Band threats.

SUMMARY: A number of advanced threats susceptible to the new UEU jammer capability available in the EA-6B were identified. These include advanced radars using pulse compression and pulsed Doppler type waveforms. Communications jamming is accomplished using the UEU to generate stable narrow band frequency spots with minimum spurious components that prevent interference with friendly communications systems. Data links can be jammed using pulse patterns generated by the UEU. Further research will identify specific waveforms and tactics to exploit the new capabilities available using the UEU.

DoD KEY TECHNOLOGY AREA: Other (Electronic Warfare)

KEYWORDS: EW, Communications Jamming

POSITIONAL ACCURACY OF TDOA MISSILE SYSTEM

D. C. Schleher, Professor
Department of Information Science
Sponsor: Naval Air Warfare Center - Weapon Division

OBJECTIVE: To analyze and synthesize an FDOA/TDOA system capable of providing a 1 m rms position accuracy from telemetry signals radiated from a test missile during flight test. Also, to investigate the accuracy of a Time, Space and Position Information (TSPII) system developed by NAWC Weapons Division, China Lake.

SUMMARY: A lower bound on the accuracy achievable using a nine base station configuration, employed at White Sands Missile Range, as a function of signal-to-noise ratio was determined. The simulation used a missile trajectory determined from measured laser tracker data. The methodology used in the simulation was to determine FDOA from each base station with respect to the reference station and then to use this to determine the TDOA of the missile. This was used in the Smith-Able algorithm to determine the position of the missile. A signal-to-noise ratio of 40 dB was required to achieve a one meter rms positional accuracy of the missile's location. The TSPI system was found to be limited by the susceptibility of the

zero crossing counter to noise and fading and the use of a wideband telemetry signal source in the missile. A system using a stable source in the missile modulated by a pseudo noise code was synthesized. This is currently under investigation using modeling and simulation techniques. An experimental test of this system is planned using a digital receiver approach.

THESIS DIRECTED:

Klaszky, R., "Analysis of the Positional Accuracy of a Range Difference Missile Position Measuring System," Masters Thesis, Naval Postgraduate School, September 2000.

Heng, C., "Kalman Filtering of FDOA/TDOA Missile Tracking System," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: TDOA, FDOA, Missile Location, TSPI, Digital Receiver

DEVELOPMENT OF SOFTWARE RELIABILITY MODEL ENHANCEMENTS

Norman Schneidewind, Professor
Department of Information Science
Sponsor: National Aeronautics and Space Administration - Goddard Space Flight Facility

OBJECTIVE: Develop and implement enhancements to the Schneidewind Software Reliability Model.

SUMMARY: In general, software reliability models have focused on modeling and predicting failure occurrence and have not given equal priority to modeling the fault correction process. However, there is a need for fault correction prediction, because there are important applications that fault correction modeling and prediction support. These are the following: predicting whether reliability goals have been achieved, developing stopping rules for testing, formulating test strategies, and rationally allocating test resources. Because these factors are related, we integrate them in our model. The modeling approach involves relating fault correction to failure prediction, with a time delay between failure detection and fault correction, represented by a random variable whose distribution parameters are estimated from observed data. The contribution is the quantification of the relationship between fault correction delay and reliability goals, which provides the software engineer with information for making informed decisions about meeting reliability goals, developing test strategies, and allocating test resources. In addition, we contribute to the state of the practice by providing a model with both failure detection and fault correction predictions.

PUBLICATIONS:

Schneidewind, N.F., "Modelling the Fault Correction Process," *Proceedings of the Twelfth International Symposium on Software Reliability Engineering*, pp. 185-190, Hong Kong, 27-30 November 2001.

Schneidewind, N.F., "Using Excel to Implement Software Reliability Models," *Notes of the Workshop on Software Assessment, the Twelfth International Symposium on Software Reliability Engineering*, Hong Kong, 27-30 November 2001.

Schneidewind, N.F., "A Roadmap To Distributed Client-Server Software Reliability Engineering," *Tutorial Notes of Quality Week 2001*, San Francisco, CA, 29 May 2001.

Schneidewind, N.F., "Introduction to Software Reliability with Space Shuttle Example," *Tutorial Notes of the 2001 Reliability and Maintainability Symposium*, IEEE Reliability Society, Philadelphia, PA, 23 January 2001.

PRESENTATIONS:

Schneidewind, N.F., "Introduction to Software Reliability Engineering with Space Shuttle Example," Temasek Laboratories, National University of Singapore, 3–4 December 2001.

Schneidewind, N.F., "Software Risk and Maintenance Stability Analysis," Temasek Laboratories, National University of Singapore, 3–4 December 2001.

Schneidewind, N.F., "Everything You Wanted to Know About SRE But Didn't Know Who to Ask", Twelfth International Symposium on Software Reliability Engineering, IEEE Computer Society Press, Hong Kong, 27-30 November 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Reliability, Modeling

DEVELOPING THE NEXT GENERATION IEEE DEPENDABILITY STANDARD: IEEE 982 STANDARD DICTIONARY OF MEASURES OF THE SOFTWARE ASPECTS OF DEPENDABILITY

Norman Schneidewind, Professor
Department of Information Science
Sponsor: IEEE Standards Board

OBJECTIVE: Develop an IEEE Software Engineering Standard for Software Dependability.

SUMMARY: This first phase of the project involves the development of measures to address reliability, maintainability, and availability. The second phase will address security, integrity, and confidentiality. This standard builds upon the IEEE 982.1 Standard Dictionary of Measures to Produce Reliable Software, but will delete outdated measures, modernize the standard with object-oriented measures, and modify measures where appropriate. Because 982 was originally issued in 1988 and has not been revised since then, much of it is obsolete. Thus, there is the need to both update existing measures and to include new measures that reflect developments in software technology since 1988. Applying the criteria on how a measure is chosen for inclusion in the dictionary, we have performed a measure-by-measure review and have added, modified, and deleted measures in the dictionary.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Standards, Software Reliability

ESTIMATING AND CONTROLLING SOFTWARE FAULT CONTENT MORE EFFECTIVELY

Norman Schneidewind, Professor
Department of Information Science
Sponsor: Jet Propulsion Laboratory, California Institute of Technology

OBJECTIVE: The goals are to develop techniques that can be used earlier in a development effort to estimate software quality attributes, particularly focusing on the way requirements changes affect software quality, and to identify relationships between specific types of structural changes to a system and the types of faults inserted into it.

SUMMARY: Software metrics have been shown to predict software quality attributes (e.g., reliability, fault content), but most of these measurements taken are of source code. However, they do not help identify the types of faults inserted into software during its development. More effective software quality control depends on the ability of measuring artifacts produced before implementation

The goals were to develop techniques that can be used earlier in a development effort to estimate software quality attributes, particularly focusing on the way requirements changes affect software quality, and to identify relationships between specific types of structural changes to a system and the types of faults inserted into it. These goals were accomplished by developing and publishing models that use requirements change risk factors as predictors of reliability. In addition, the relationship between requirements change risk factors and software metric critical values was modeled. It was shown that when these critical values are exceeded, it is indicative of unreliable software.

PUBLICATIONS:

Schneidewind, N.F., "Life Cycle Core Knowledge Requirements for Software Quality Measurement," *IEEE Computer*, Computer Society Press, Los Alamitos, CA, 2002 (accepted for publication).

Schneidewind, N.F., "Maintenance Process and Product Evaluation Using Reliability, Risk, and Test Metrics," *Advances in Computers*, Academic Press, Vol. 54, pp. 153-181, 2001.

Schneidewind, N.F., "SRE of Web Site Construction," *Tutorial Notes of the Twelfth International Symposium on Software Reliability Engineering*, Hong Kong, 27-30 November 2001.
Schneidewind, N.F., "Investigation of the Risk to Software Reliability and Maintainability of Requirements Changes," *Proceedings of the International Conference on Software Maintenance*, Florence, Italy, pp. 127-136, 7-9 November 2001.

Schneidewind, N.F., "Web Site Maintainability," *Proceedings of the Seventh Workshop on Empirical Studies of Software Maintenance*, Florence, Italy, pp. 29-30, 9 November 2001.

Schneidewind, N.F., "Knowledge Requirements for Software Quality Measurement," *Journal of Empirical Software Engineering*, Kluwer Academic Publishers, Vol. 6, No.3, pp. 201-205, September 2001.

Schneidewind, N.F., "Requirements Risk Analysis and the AIAA Recommended Practice for Software Reliability," *Proceedings of the Space 2001 Conference*, American Institute of Aeronautics and Astronautics, Albuquerque, NM, 28 August 2001.

Schneidewind, N.F., "Software Requirements Risk and Reliability," *Proceedings of the Monterey Workshop 2001*, Naval Postgraduate School, Monterey, CA, pp. 275-284, 18-22 June 2001.

Schneidewind, N.F., "Investigation of Logistic Regression as a Discriminant of Software Quality," *Proceedings of the 7th International Software Metrics Symposium*, London, UK, pp. 328-337, 4-6 April 2001.

Schneidewind, N.F., "Data Analysis of Software Requirements Risk," *Proceedings of the 12th European Software Control and Metrics Conference*, London, UK, pp. 443-451, 2-4 April 2001.

Schneidewind, N.F., "SRE of Web Site Construction," *Tutorial Notes of The Twelfth International Symposium on Software Reliability Engineering*, Hong Kong, 41 pp., 27-30 November 2001.

Schneidewind, N.F., "Using Excel to Implement Software Reliability Models," *Notes of the Workshop on Software Assessment,* The Twelfth International Symposium on Software Reliability Engineering, Hong Kong, 29 pp., 27-30 November 2001.

Schneidewind, N.F., "A Roadmap To Distributed Client-Server Software Reliability Engineering," *Tutorial Notes of Quality Week 2001*, San Francisco, CA, 20 pp., 29 May 2001.

Schneidewind, N.F., "Introduction to Software Reliability with Space Shuttle Example," *Tutorial Notes of the 2001 Reliability and Maintainability Symposium*, IEEE Reliability Society, Philadelphia, PA, 29 pp., 23 January 2001.

PRESENTATIONS:

Schneidewind, N.F., "SRE of Web Site Construction," Twelfth International Symposium on Software Reliability Engineering, Hong Kong, 27-30 November 2001.

Schneidewind, N.F., "Investigation of the Risk to Software Reliability and Maintainability of Requirements Changes," International Conference on Software Maintenance, Florence, Italy, 7-9 November 2001.

Schneidewind, N.F., "Web Site Maintainability," Seventh Workshop on Empirical Studies of Software Maintenance, Florence, Italy, 9 November 2001.

Schneidewind, N.F., "Requirements Risk Analysis and the AIAA Recommended Practice for Software Reliability," Space 2001 Conference, American Institute of Aeronautics and Astronautics, Albuquerque, NM, 28 August 2001.

Schneidewind, N.F., "Investigation of Logistic Regression as a Discriminant of Software Quality," 7th International Software Metrics Symposium, London, UK, 4-6 April 2001.

Schneidewind, N.F., "Data Analysis of Software Requirements Risk," 12th European Software Control and Metrics Conference, London, UK, 2-4 April 2001.

Schneidewind, N.F., "Introduction to Software Reliability Engineering with Space Shuttle Example," Temasek Laboratories, National University of Singapore, 3-4 December 2001.

Schneidewind, N.F., "Software Risk and Maintenance Stability Analysis," Temasek Laboratories, National University of Singapore, 3-4 December 2001.

Schneidewind, N.F., "Everything You Wanted to Know About SRE But Didn't Know Who to Ask," Twelfth International Symposium on Software Reliability Engineering, IEEE Computer Society Press, Hong Kong, 27-30 November 2001.

Schneidewind, N.F., "Measuring and Evaluating Maintenance Process Using Reliability, Risk, and Test Metrics," IEEE Computer Society Chapters and Tutorials Program, Greensboro, NC, 19 July 2001.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Reliability, Software Metrics, Modeling

MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM

George Zolla, Lecturer
Department of Information Science
Sponsor: Federal Aviation Administration

OBJECTIVE: To design a distributed database management system that would capture maintenance factors that have contributed to past aircraft mishaps and make these factors available to users with the goal of reducing future aircraft mishap rates.

SUMMARY: The Human Factors Analysis and Classification System-Maintenance Extension taxonomy (HFACS-ME), a framework for classifying and analyzing the presence of maintenance errors that lead to mishaps, incidents, and personal injuries, is the theoretical foundation for the system. An existing desktop mishap application was updated, a prototype web-based model was developed and an Asynchronous Distributed Learning (ADL) module was conceptualized. These tools were designed to facilitate data collection, organization, query, analysis, and the reporting of maintenance errors that contribute to aviation mishaps. Together they represent a complete, robust system for analyzing aircraft maintenance mishap related factors anywhere at anytime.

PUBLICATIONS:

Zolla, G, Boex, T., Flanders, P. and Nelson, D., "Distributed Maintenance Error Information, Investigation and Intervention," *World Aviation Conference Proceedings*, Seattle, WA, 2001.

Zolla, G., Flanders, P. and Boex, T., "Web-Based Information Management of Maintenance Errors in Aviation Mishaps," *Fourth International Conference on Electronic Commerce Research Proceedings*, Dallas, TX, 2001.

PRESENTATIONS:

Zolla, G., "Distributed Maintenance Error Information, Investigation and Intervention," World Aviation Conference, Seattle, WA, 11-14 September 2001.
Zolla, G., "Web-Based Information Management of Maintenance Errors in Aviation Mishaps," Fourth International Conference on Electronic Commerce Research, Dallas, TX, 8-11 November 2001.

THESIS DIRECTED:

Boez, T., "Web-Based Information Management System for the Investigation, Reporting and Analysis of Human Error in Naval Aviation Maintenance," Masters Thesis, Naval Postgraduate School, September 2001.

Nelson, D., "Information Management System Development for the Investigation, Reporting and Analysis of Human Error in Naval Aviation Maintenance," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software

KEYWORDS: Aviation Safety, Maintenance Error Information, Mishap Investigations, Distributed Mishap Information

DEPARTMENT OF INFORMATION SCIENCE

2001
Faculty Publications and Presentations

JOURNAL PAPERS

Schneidewind, N.F., "Maintenance Process and Product Evaluation Using Reliability, Risk, and Test Metrics," *Advances in Computers*, Academic Press, Vol. 54, pp. 153-181, 2001.

Schneidewind, N.F., "Knowledge Requirements for Software Quality Measurement," *Journal of Empirical Software Engineering*, Kluwer Academic Publishers, Vol. 6, No. 3, pp. 201-205, September 2001.

CONFERENCE PAPERS

Schneidewind, N.F., "Modelling the Fault Correction Process," *Proceedings of the Twelfth International Symposium on Software Reliability Engineering*, Hong Kong, pp. 185-190, 27-30 November 2001.

Schneidewind, N.F., "Using Excel to Implement Software Reliability Models," *Notes of the Workshop on Software Assessment, Twelfth International Symposium on Software Reliability Engineering*, Hong Kong, 29 pp., 27-30 November 2001.

Schneidewind, N.F., "A Roadmap To Distributed Client-Server Software Reliability Engineering," *Tutorial Notes of Quality Week 2001*, San Francisco, CA, 20 pp., 29 May 2001.

Schneidewind, N.F., "Introduction to Software Reliability with Space Shuttle Example," *Tutorial Notes of the 2001 Reliability and Maintainability Symposium*, IEEE Reliability Society, Philadelphia, PA, 23 January 2001.

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Schneidewind, N.F., "Investigation of the Risk to Software Reliability and Maintainability of Requirements Changes," *Proceedings of the International Conference on Software Maintenance*, Florence, Italy, pp. 127-136, 7-9 November 2001.

Schneidewind, N.F., "Requirements Risk Analysis and the AIAA Recommended Practice for Software Reliability," *Proceedings of the Space 2001 Conference*, American Institute of Aeronautics and Astronautics, Albuquerque, NM, 10 pp., 28 August 2001.

Schneidewind, N.F., "Software Requirements Risk and Reliability," *Proceedings of the Monterey Workshop 2001*, Naval Postgraduate School, Monterey, CA, pp. 275-284, 18-22 June 2001.

Schneidewind, N.F., "Investigation of Logistic Regression as a Discriminant of Software Quality," *Proceedings of the 7th International Software Metrics Symposium*, London, UK, pp. 328-337, 4-6 April 2001.

Schneidewind, N.F., "Data Analysis of Software Requirements Risk," *Proceedings of the 12th European Software Control and Metrics Conference*, London, UK, pp. 443-451, 2-4 April 2001.

Zolla, G., Boex, T., Flanders, P. and Nelson, D., "Distributed Maintenance Error Information, Investigation and Intervention," *World Aviation Conference Proceedings*, Seattle, WA, 2001.

Zolla, G., Flanders, P. and Boex, T., "Web-Based Information Management of Maintenance Errors in Aviation Mishaps," *Fourth International Conference on Electronic Commerce Research Proceedings*, Dallas, TX, 2001.

CONFERENCE PRESENTATIONS

Schneidewind, N.F., "Everything You Wanted to Know About SRE But Didn't Know Who to Ask", Twelfth International Symposium on Software Reliability Engineering, IEEE Computer Society Press, Hong Kong, 27-30 November 2001.

Schneidewind, N.F., "SRE of Web Site Construction," the Twelfth International Symposium on Software Reliability Engineering, Hong Kong, 27-30 November 2001.

Schneidewind, N.F., "Investigation of the Risk to Software Reliability and Maintainability of Requirements Changes," International Conference on Software Maintenance, Florence, Italy, 7-9 November 2001.

Schneidewind, N.F., "Web Site Maintainability," Seventh Workshop on Empirical Studies of Software Maintenance, Florence, Italy, 9 November 2001.

Schneidewind, N.F., "Requirements Risk Analysis and the AIAA Recommended Practice for Software Reliability," Space 2001 Conference, American Institute of Aeronautics and Astronautics, Albuquerque, NM, 28 August 2001.

Schneidewind, N.F., "Measuring and Evaluating Maintenance Process Using Reliability, Risk, and Test Metrics," IEEE Computer Society Chapters and Tutorials Program, Greensboro, NC, 19 July 2001.

Schneidewind, N.F., "Investigation of Logistic Regression as a Discriminant of Software Quality," 7th International Software Metrics Symposium, London, UK, 4-6 April 2001.

Schneidewind, N.F., "Data Analysis of Software Requirements Risk," 12th European Software Control and Metrics Conference, London, UK, 2-4 April 2001.

Zolla, G., "Distributed Maintenance Error Information, Investigation and Intervention," World Aviation Conference, Seattle, WA, 11-14 September 2001.

Zolla, G., "Web-Based Information Management of Maintenance Errors in Aviation Mishaps," Fourth International Conference on Electronic Commerce Research, Dallas, TX, 8-11 November 2001.

TECHNICAL REPORTS

Osmundsen, J.S, Schleher, D.C. and Harney, R.C., *Identification of Potential Adversary Systems and Technologies to Disrupt US Naval Operations, ANTI-ACCESS SYSTEMS STUDY*, Naval Postgraduate School Technical Report, NPS-JW-01-015, 31 January 2001.

DEPARTMENT OF OPERATIONS RESEARCH

JAMES EAGLE
CHAIR

OPERATIONS RESEARCH

OVERVIEW:

The Naval Postgraduate School Operations Research (OR) program is a world-class curriculum designed to teach students the science of helping people and organizations make better decisions.

This science is necessary in today's increasingly complex operating environment in which officers and managers must respond quickly to a vast array of demands while also weighing the options and consequences of each into his or her final decision. OR offers a scientific approach through the use of many tools and techniques in order to assist an individual in his or her decision making process.

The military specifically uses OR at the strategic, operational, and tactical levels. OR applications cover the gamut of military activities including: National policy analysis, resource allocation, force composition and modernization, logistics, human resources, battle planning, flight operations scheduling, intelligence, command and control, weapon selection, engagement tactics, maintenance and replenishment, and search and rescue.

The Department of Operations Research mission is:

- To educate analysts who are fully capable of conducting independent analytical studies of military problems, and have an educational basis for continued learning and development.
- To provide the United States government and our allies with military officers who have a comprehensive knowledge of military operations research, and who can perform and manage quantitative analysis of operational and other Defense problems.
- To provide operations research and general analysis support to DoD.
- To develop and maintain a world-class research program in operations research and related areas.

CURRICULA SERVED:

- Modeling, Virtual Environments and Simulation (MOVES)
- Electronic Warfare Systems International
- Information Systems and Operations
- Information Systems Technology
- Information Warfare
- Joint C4I
- Intelligence Information Management
- Naval/Mechanical Engineering
- Operations Analysis
- Operational Logistics
- Advanced Science (Applied Math)
- Product Development 21
- Space Systems Operations International
- Space Systems Operations
- Systems Engineering/Integration
- Manpower Systems Analysis
- Undersea Warfare
- Undersea Warfare International

DEGREES GRANTED:

- Master of Science in Operations Research
- Master of Science in Applied Science
- Doctor of Philosophy

RESEARCH THRUSTS:

- Probability and Stochastic Processes
- Optimization
- Statistics and Data Analysis
- Human Factors and Systems Integration
- Simulation and War Gaming
- Search, Detection and Evasion

RESEARCH CHAIRS:

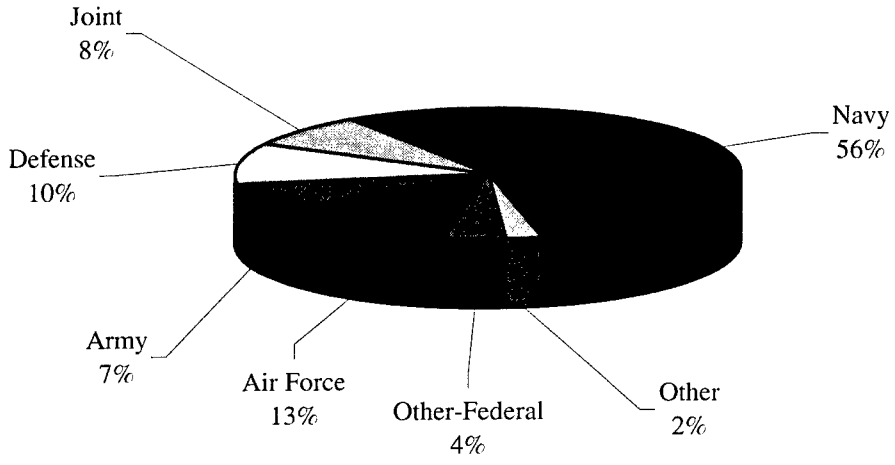
- Chair for Manpower Modeling
- Chair of Applied Systems Analysis
- Chair of Tactical Analysis

RESEARCH FACILITIES:

- Secure Computing and Simulation Lab (WARLAB)
- Optimization Lab
- Human Systems Integration Laboratory (HISL)

RESEARCH PROGRAM (Research and Academic)-FY2001:

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



Size of Program: **$2290K**

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CHAIR OF APPLIED SYSTEMS ANALYSIS

CDR Matthew G. Boensel, USN
Department of Operations Research
Sponsor: Chief of Naval Operations–Assessment Division (N81)

OBJECTIVE: In accordance with the current Memorandum of Understanding between the Superintendent, Naval Postgraduate School and N81 (dated 12 April 1993), funds will provide research support for analysis of issues of interest to the Navy. Research will provide professional development of NPS faculty and students.

SUMMARY: Specific elements of this project include:

- Support for student thesis tours, in association with the OA program office.
- Support for faculty development in applied systems analysis and faculty travel to DC in support of N81 activities.
- Support for student and faculty travel for thesis research projects.

Of note, a special short course refresher on Operations Research methods was developed and delivered for action officers in the Assessment Division (N81).

PRESENTATIONS:

Washburn, A., "Introduction to Military Operations Research," Pentagon, Arlington, VA, 21-25 May 2001.

THESIS DIRECTED:

Borden, K., "Optimizing the Number and Employment of Combat Logistics Force Shuttle Ships, with a Case Study of the New T-AKE Ship," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Other (Operations Research)

KEYWORDS: Optimization, Operations Research, Combat Logistics

AN ARCHITECTURE FOR DYNAMIC PLANNING SYSTEMS USING LOOSELY COUPLED COMPONENTS

Gordon H. Bradley, Professor
Arnold H. Buss, Assistant Professor
Department of Operations Research
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Design and develop an architecture for dynamic map-based military planning applications using new platform-independent software technology. This is a continuing research project.

SUMMARY: The research has designed and developed a "loosely coupled components" architecture that has been demonstrated by constructing a map-based planning system for dynamic military planning. The architecture coordinates a collection of components that operate over heterogeneous computer networks. The system accesses and displays data, maps, overlays, algorithms, and other information. The components perform tasks such as: displaying maps, satellite images, and overlays; accessing, entering, and modifying data; constructing and displaying models of military operations; and accessing and executing algorithms to analyze operations. The design allows systems to be easily extended by adding addition components.

PRESENTATIONS:

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G., "M&S in Classroom Instruction and Thesis Research at the Naval Postgraduate School," NAVMSMO Technical Interchange Meeting, National Defense University, Ft. McNair, Washington, DC, 23 August 2001.

THESES DIRECTED:

Fricke, C., "Operational Logistics Wargame," Masters Thesis, Naval Postgraduate School, December 2001.

San Jose, A., "Analysis, Design, Implementation and Evaluation of Graphical Design Tool to Develop Discrete Event Simulation Models Using Event Graphs and Simkit," Masters Thesis, Naval Postgraduate School, September 2001.

Lenhardt, T., "Evaluation of Combat Service Support Logistics Concepts for Supplying a USMC Regimental Task Force," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Project Monterey: A system to support real-time and near real-time military decision-making using network models based on the Loosely Coupled Components Architecture (LCCA).

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

LARGE-SCALE OPTIMIZATION

Gordon H. Bradley, Professor
Gerald G. Brown, Distinguished Professor
R. Kevin Wood, Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models, and develop graph and network algorithms for dynamic map-based military planning. This is a continuing research project.

SUMMARY: One part of this research developed a new algorithm called BEST (Bound, Enumerate, Sample and Test) for solving two-stage stochastic integer programs. The algorithm has been applied to network-interdiction problems with uncertain interdiction success. Another part of this research designed and developed a toolkit of methods to quickly construct graph and network algorithms. The algorithms were integrated into a dynamic map-based military planning system that operates over heterogeneous computer networks. The system can download algorithms over a computer network and execute them to analyze operations. The design allows algorithms to be easily added to the planning system.

PUBLICATIONS:

Brown, G., Keegan, J., Vigus, B. and Wood, K., "The Kellogg Company Optimizes Production, Inventory and Distribution," *Interfaces*, Vol. 31, pp. 1-15, 2001.

Israeli, E. and Wood, K., "Shortest-Path Network Interdiction," in review.

PRESENTATIONS:

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G., "M&S in Classroom Instruction and Thesis Research at the Naval Postgraduate School," NAVMSMO Technical Interchange Meeting, National Defense University, Ft. McNair, Washington, DC, 23 August 2001.

Brown, G., "Fast Theater Attack Model," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Brown, G., Byrne, P. and Washburn, A., "Fast Theater Model (FATHM)," 69th Military Operations Research Society Symposium, U. S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Dell, R.F., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Newman, A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Morton, D., Salmeron, J. and Wood, K., "A Sampling-Based Cutting-Plane Method for Stochastic Programs," INFORMS National Meeting, Miami Beach, FL, 4-7 November 2001.

Morton, D., Salmeron, J. and Wood, R.K., "A Stochastic Program for Optimizing Military Sealift Subject to Attack," Workshop on Decision-Making Under Uncertainty, Molde, Norway, 18-20 May 2001.

Sanchez, S. and Wood, K., "Solving Stochastic Network Interdiction Problems with the Partially Enumerate Then Screen Method," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Mathematics Department Seminar, University of California at Davis, Davis, CA, 5 October 2001.

Wood, K., "Network Interdiction," Sandia National Laboratories, Albuquerque, NM, 2 July 2001.

THESES DIRECTED:

Bingol, L., "A Lagrangian Heuristic for Solving a Network Interdiction Problem," Masters Thesis, Naval Postgraduate School, December 2001.

Borden, K.D., "Optimizing the Number and Employment of Combat Logistics Force Shuttle Ships, with a Case Study of the New T-AKE Ship," Masters Thesis, Naval Postgraduate School, September 2001.

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

Kubu, J.A., "Enhancing Real-time Tomahawk Predesignation to Diagnose Conflicts, Prescribe Improvements, and Plan Multiple Strikes," Masters Thesis, Naval Postgraduate School, September 2001.

Wingeart, P.H., "An Improved Heuristic for Tomahawk Land-Attack Predesignation, Enhanced to Accommodate Manual Planning and Validated with Fleet Exercise Data," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming, Dynamic Planning

FAST THEATER MODEL

Gerald G. Brown, Distinguished Professor
Alan Washburn, Professor
Department of Operations Research
Sponsors: Joint Staff (J8) and the Naval Postgraduate School

OBJECTIVE: Provide support to the Joint Chiefs of Staff in improving FATHM, the FAst THeater Model.

SUMMARY: FATHM is an aggregated combat model that is part optimization and part simulation, a hybrid model. Air-to-ground activity is optimized, while ground-to-ground activity is simulated using a Lanchester model that imitates COSAGE, a high-resolution simulation. Progress in FY2001 includes

- a mechanism for target valuation
- based on target valuation, a mechanism for calculating force ratios and FEBA movement
- direct calls to an LP solver, a more efficient method than indirect calls via GAMS
- an improved method for calculating Lanchester coefficients based on the COSAGE killer-victim scoreboard
- improved input and output procedures

PUBLICATIONS:

Washburn, A., *The Fast Theater Model (FATHM)*, Naval Postgraduate School Technical Report, NPS-OR-01-002-PR, 2001.

PRESENTATIONS:

Brown, G., Byrne, P. and Washburn, A., "The Fast Theater Model," 69th Military Operations Research Society Symposium, 12-14 June 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Optimization, Weapon Allocation

LARGE-SCALE OPTIMIZATION

Gerald G. Brown, Distinguished Professor
R. Kevin Wood, Professor
Department of Operations Research
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models and mathematical programs. Develop extensions of network-interdiction techniques to solve more general system interdiction models.

SUMMARY: Have completed and delivered to JCS/J8 and U.S. Army Center for Army Analysis, Ft. Belvoir, Virginia, the Fast Theater Model (FATHM), an integrated air-to-ground attack model (using large-

scale optimization) and ground-to-ground model (using Lanchester equations). FATHM runs full-scale theater wars in less than five minutes with all the fidelity expected by Air Force and Army planners. The goal is to distribute targets among our forces optimally, and also to gauge the weapons and platform requirements to win. In other research areas, a Lagrangian-relaxation technique has been developed for quickly solving certain network-interdiction problems, and have an extension of integer cutting planes for solving integer programs has been devised Unlike standard cuts, the "super-valid inequalities" can cut away valid integer solutions, but they are guaranteed to not cut away useful solutions.

PUBLICATIONS:

Brown, G., Keegan, J., Vigus, B. and Wood, K., "The Kellogg Company Optimizes Production, Inventory and Distribution," *Interfaces*, Vol. 31, pp. 1-15, 2001.

Israeli, E. and Wood, K., "Shortest-Path Network Interdiction," in review.

PRESENTATIONS:

Brown, G.G., "Fast Theater Attack Model," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Brown, G.G., Byrne, P. and Washburn, A., "Fast Theater Model (FATHM)," 69th Military Operations Research Society Symposium, U. S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Dell, R.F., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Newman, A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Morton, D., Salmeron, J. and Wood, K., "A Sampling-Based Cutting-Plane Method for Stochastic Programs," INFORMS National Meeting, Miami Beach, FL, 4-7 November 2001.

Morton, D., Salmeron, J. and Wood, R.K., "A Stochastic Program for Optimizing Military Sealift Subject to Attack," Workshop on Decision-Making Under Uncertainty, Molde, Norway, 18-20 May 2001.

Sanchez, S. and Wood, K., "Solving Stochastic Network Interdiction Problems with the Partially Enumerate Then Screen Method," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Mathematics Department Seminar, University of California at Davis, Davis, CA, 5 October 2001.

Wood, K., "Network Interdiction," Sandia National Laboratories, Albuquerque, NM, 2 July 2001.

THESES DIRECTED:

Bingol, L., "A Lagrangian Heuristic for Solving a Network Interdiction Problem," Masters Thesis, Naval Postgraduate School, December 2001.

Borden, K.D., "Optimizing the Number and Employment of Combat Logistics Force Shuttle Ships, with a Case Study of the New T-AKE Ship," Masters Thesis, Naval Postgraduate School, September 2001.

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

Kubu, J.A., "Enhancing Real-time Tomahawk Predesignation to Diagnose Conflicts, Prescribe Improvements, and Plan Multiple Strikes," Masters Thesis, Naval Postgraduate School, September 2001.

Wingeart, P.H., "An Improved Heuristic for Tomahawk Land-Attack Predesignation, Enhanced to Accommodate Manual Planning, and Validated with Fleet Exercise Data," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Other (Optimization, Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming, Network Interdiction

OPTIMIZING NAVY PROGRAM PLANNING

Gerald G. Brown, Distinguished Professor
Robert F. Dell, Associate Professor
Anton Rowe, Research Associate
Javier Salmeron, Research Assistant Professor
Department of Operations Research
Sponsor: Chief of Naval Operations (N81)

OBJECTIVE: To provide N81 with a desktop, optimization-based decision-support tool to integrate, rationalize, and schedule the way in which and the rate at which Navy capital spending programs should be conducted over the next 25 years.

SUMMARY: A prototype custom-built optimization-based decision-support system was delivered complete with graphical user interface and custom heuristic. The decision-support system prescribes complete scenarios that can follow all Navy guidelines, including details such as keeping shipyards efficiently employed, constraining aircraft average age, and meeting IWARS (Integrated Warfare Architecture) requirements. Without the system, complete scenarios must be manually assembled, which is a laborious, error-prone task. Efforts continue to improve the system.

PRESENTATIONS:

Dell, R.F. and Brown, G.G., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

THESIS DIRECTED:

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

OTHER:

Software: The following versions of the decision support system were delivered to N81.

Version	Delivered	Comments	Documentation
P.01.01	02/28/01	Prototype Interface. Heuristic Solver	No
P.03.03	06/04/01	Prototype Interface. Heuristic Solver	No
P.07.04	11/13/01	Prototype/semi-operative Interface. Heuristic Solver	Yes

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization, Large-Scale Optimization, Program Planning, Budgeting, Capital Budgeting

OPTIMIZING TOMAHAWK LAND ATTACK PREDESIGNATION

Gerald G. Brown, Distinguished Professor
Department of Operations Research
Alexandra M. Newman, Assistant Professor
Colorado School of Mines
Richard E. Rosenthal, Professor
Department of Operations Research
Sponsors: Naval Surface Warfare Center - Dahlgren Division and Office of Naval Research

OBJECTIVE: Testing and refining a heuristic procedure to efficiently assign tasks requiring Tomahawk Land-Attack Missiles (TLAMs) to the firing platforms of a battle group, i.e., surface ships and submarines.

SUMMARY: A fast heuristic was developed to assign Tomahawk missiles to firing platforms. Solutions obtained with this heuristic were compared against those obtained manually by the Tomahawk Strike Coordinator, i.e., using current practice. The heuristic solutions are of better quality than the manual ones and can be obtained much more quickly than with any manual process. Additionally, the heuristic was enhanced to incorporate these operational features: (i) The ability to plan subsequent tasking before the execution of the current tasking; (ii) the ability to manually allocate tasks to firing platforms with the guidance of the heuristic; and (iii) a function for identifying why certain tasks might not be able to be assigned to firing platforms, and for suggesting task-list modifications that would make it possible to accommodate those tasks.

PUBLICATIONS:

Brown, G.G., Newman, A.M, Rosenthal, R.E. and Rowe, A.A., *Optimizing Tomahawk Strikes*, Naval Postgraduate School Technical Report, NPS-OR-01-001-PR, January 2001, (also appeared in *Naval Postgraduate School Research Newsletter*).

PRESENTATIONS:

Brown, G.G., Newman, A.M., Rosenthal, R.E. and Rowe, A.A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

THESES:

Kubu, J.A., "Enhancing Real-time Tomahawk Predesignation to Diagnose Conflicts, Prescribe Improvements, and Plan Multiple Strikes," Masters Thesis, Naval Postgraduate School, September 2001.

Wingeart, P.H., "An Improved Heuristic for Tomahawk Land-Attack Predesignation, Enhanced to Accommodate Manual Planning, and Validated with Fleet Exercise Data," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Surface/Under Surface Vehicles, Ships and Watercraft

KEYWORDS: Missiles, Missile Selection, Naval Operations, Tomahawk Land Attack Missile

MARITIME OPERATIONS SIMULATION AND APPLICABILITY ASSESSMENT FOR DEEPWATER

Arnie Buss, Assistant Professor
Department of Operations Research
Sponsor: United States Coast Guard

OBJECTIVE: Determine if contractor-supplied software tools will meet the Coast Guard's needs for modeling deepwater acquisition.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Deepwater Acquisition, Simulation, Validation

ANALYSIS IN SUPPORT OF USMC PME SURVEY

Samuel E. Buttrey, Assistant Professor
Lyn R. Whitaker, Associate Professor
Department of Operations Research
Sponsor: Marine Corps Combat Development Command

OBJECTIVE: To provide support to the Studies and Analysis Division (S&A), Marine Corps Combat Development Command for completion of the Marine Corps Professional Military Education (PME) Study. Specifically, to provide assistance with survey question development, survey data analysis, and to be the principal performers of data mining and analysis of existing Marine Corps databases in order to complete Tasks 2-4 in the PME Study Directive.

SUMMARY: This research project was a short fuse project with very specific deliverables. The primary purpose of NPS involvement was to provide S&A with any statistical support needed in their study of PME for the Marine Corps University. All deadlines and deliverables were met. These included help with constructing and on-line survey administered to all USMC officers. This survey captured views of officers about their PME experiences and their views of the importance and impact on USMC of resident and nonresident PME. Extensive summary statistics, corresponding graphics and interpretation of the results of this survey were delivered to S&A. These were incorporated into the final report. In addition, the Center for Naval Analysis data base, the USMC officer "Street to Fleet" data was scrutinized to see if there was any relationship between PME history and success as measured by promotion to various ranks and length of retention. The results of this analysis, including descriptive statistics and model fits to account for other variables influencing success, were delivered to S&A in the form of an interim report. These results were also used in the final report. Because the primary role of NPS was support for S&A's study, the results of NPS's contributions are integrated into S&A's report: "Professional Military Education Study for Marine Corps University: Final Report" (2001).

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Professional Military Education (PME), Manpower, Education

ANALYSIS OF PRE SOURCE INFORMATION

Samuel E. Buttrey, Assistant Professor
Department of Operations Research
Sponsor: Personnel Security Research Center

OBJECTIVE: To provide support to PERSEREC in analyzing the quality of information provided to their investigators by different sources with regard to different security considerations.

SUMMARY: This research project supported PERSEREC in measuring the quality of the information provided by different sources in their investigation of personnel receiving security clearances. Particular

attention was paid to the problem of inter-rater reliability (gauging the extent to which different investigators reach the same conclusions when presented with the same report), or IRR. The results of this analysis, including descriptive statistics, test of hypothesis, and measures of IRR were delivered to PERSEREC for inclusion in that organization's final report.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Manpower, Security Clearance, Inter-rater Reliability

OPTIMIZATION MODELS FOR INSTALLATION MANAGEMENT

Robert F. Dell, Associate Professor
Department of Operations Research
Sponsor: U.S. Army, Assistant Chief of Staff for Installation Management

OBJECTIVE: Develop optimization models to assist with installation management.

SUMMARY: The investigator is providing research, support, and development of optimization models to assist the Army's Assistant Chief of Staff for Installation Management. The integer-linear programs OSAF (Optimal Stationing of Army Forces) and BAEC (Budget Allocation for Environmental Cleanup) were the primary 2001 development effort. The Center for Army Analysis used OSAF for numerous stationing studies and to help answer a QDR (Quadrennial Defense Review) issue: "What are the infrastructure requirements to support the Army of the future?" The Army's Base Realignment and Closure Office used BAEC to help plan $414 million in environmental cleanup at 334 sites on 54 current and former Army installations.

PUBLICATIONS:

Connor, G., Dell, R.F. and Tarantino, W.J., "An Integer Linear Program to Recommend Stationing of Army Forces," 27 November 2001. (Draft paper selected as a Finalist for 2001 Military Operations Research Richard H. Barchi Prize.)

PRESENTATIONS:

Tarantino, W.J, Dell, R.F. and Connor, G., "Optimal Stationing of Army Forces (OSAF)," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Tarantino, W.J., "Optimal Stationing of Army Forces," National Meeting of the Institute for Operations Research and the Management Sciences, Miami Beach, FL, 4-7 November 2001.

THESES DIRECTED:

Ardic, S., "Funding Site Cleanup at Closing Army Installations: A Stochastic Optimization Approach," Masters Thesis, Naval Postgraduate School, December 2001.

Gezer, M., "Optimal Stationing of the United States Army Forces in Korea," Masters Thesis, Naval Postgraduate School, December 2001.

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

KEYWORDS: BRAC, Capital Budgeting, Optimization, Mixed Linear Integer Programming Application

PLANNING CAPITAL INVESTMENTS USING OPTIMIZATION

Robert F. Dell, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Conduct research in optimal planning of capital investments with two short-term subjects, (a) the Capital Investment Planning Aide (CIPA) for U.S. Navy Force Structure planning and (b) the Japan Petroleum Distribution model (JPDM) for U.S. Navy infrastructure planning.

SUMMARY: This effort to conduct research on theory and algorithms for solving real-world capital budgeting problems with prescriptive optimization had two short-term goals. The first was to enhance the Capital Investment Planning Aide (CIPA) for U.S. Navy Force Structure planning. We have formulated an optimization model of the Navy's spending plans for major weapons systems (e.g., ships and aircraft) and demonstrated it with current planning data. The second short-term goal was to enhance the Japan Petroleum Distribution model (JPDM) for U.S. Navy infrastructure planning. Several new models were developed.

PRESENTATIONS:

Dell, R.F. and Brown, G.G, "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Noble, J.D., "Scheduling and Distributing Intra-Theatre Wartime POL Requirements," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

THESES DIRECTED:

Devlin, D.L., "Scheduling and Distributing Intra-Theater Wartime POL Requirements Under Uncertainty," Masters Thesis, Naval Postgraduate School, December 2001.

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

Harmon, J.V., "Planning U.S. Pacific Command Wartime Fuel Distribution," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Software: The following versions of CIPA were delivered to N81.

Version	Delivered	Comments	Documentation
P.01.01	02/28/01	Prototype Interface. Heuristic Solver	No
P.03.03	06/04/01	Prototype Interface. Heuristic Solver	No
P.07.04	11/13/01	Prototype/semi-operative Interface. Heuristic Solver	Yes

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization, Large-Scale Optimization, Program Planning, Budgeting, Capital Budgeting, Other (Optimization and Decision Support)

OPTIMIZING THE FLOW OF MARINE RECRUITS THROUGH ENTRY-LEVEL TRAINING

Robert F. Dell, Associate Professor
Javier Salmeron, Research Assistant Professor
Department of Operations Research
Sponsor: U.S. Marine Corps Combat Development Command

OBJECTIVE: Assist the Marine Corps in developing an optimization model to prescribe a flow of enlisted recruits through entry-level training.

SUMMARY: The Marine Corps viewed the total time non-infantry enlisted wait for MOS training as unacceptably high. Integer linear programs were developed that model the flow of enlisted recruits through entry-level training. The models' recommendations highlight how more coordinated actions by recruiting planners and military occupational schools can significantly reduce the total Marine-year wait time. Tests carried out employing recent data show reductions of more than 50 percent.

THESIS DIRECTED:

Whaley, D.L., "Scheduling the Recruiting and MOS Training of Enlisted Marines," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel and Training, Modeling and Simulation, Other (Optimization)

KEYWORDS: Integer Optimization, Scheduling, Resource Constrained Problems

NAVY AIRLIFT

William Gates, Associate Professor
Graduate School of Business and Public Policy
Alan Washburn, Professor
Department of Operations Research
Sponsor: Chief of Naval Operations (N78)

OBJECTIVE: The Navy operates a fleet of operational support aircraft (OSA) that have the function of moving high priority passengers and cargo in wartime. The fleet is aging, and must gradually be replaced with more modern aircraft. The objective is first to measure the wartime demand for OSA transport in the event of a major war, and then to design a fleet that satisfies that demand at minimal cost.

SUMMARY: The basic approach is to estimate wartime demand for OSA transport, and then design a fleet that can meet that demand efficiently, bearing in mind that the costs of current OSA aircraft are "sunk." A fleet management tool OSAMIX is developed as an Excel workbook. Peacetime demand is estimated by recovering appropriate records from the JALIS database system, and then inflated to prospective wartime demand by applying a "surge factor." Given the characteristics of various aircraft, OSAMIX then finds the fleet that minimizes the present value of the costs of meeting that demand. One conclusion is that it is cost-effective for the Navy to retire its fleet of C-12 turboprop aircraft in favor of a similarly scaled jet aircraft.

PUBLICATIONS:

Gates, W. and Washburn, A., *The Navy Operational Support Aircraft Fleet*, Naval Postgraduate School Technical Report, NPS-OR-01-006-PR, 2001.

THESIS DIRECTED:

Law, J., "Assessing the Performance and Cost of Logistics Airfleet Options," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: OSA, Operational Support Aircraft, Cost-Effective

ANALYTICAL DECISION-SUPPORTING RESEARCH USING SYNTHESIZED ADAPTIVE-AGENT-BASED MODELING AND MATHEMATICAL MODELING

Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: The Modeling, Virtual Environments and Simluation (MOVES) Institute

OBJECTIVE: Purpose of the research is to formulate and study models for the adaptive scheduling of time critical tasks under imperfect information in joint warfare with a view towards guiding allocation of acquisition and eventually operational resources. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems on interactive and joint conflicts. The purpose of the modeling and analysis is to explore the advantages of using Genetic Algorithms in the adaptive scheduling of processing of time-critical tasks, with imperfectly known identity and arriving in random streams of "unknown," i.e., changing, properties. This is a generalization of the General Assignment Problem (GAP) treated (under assumptions of certainty) by mathematical programming. The models here are called the Generalized Generalized Assignment Problem (GGAP).

SUMMARY: Models for allocation of service to time-critical tasks with uncertain outcomes have been formulated.

PUBLICATIONS:

Glazebrook, K.D., Gaver, D.P. and Jacobs P.A., *On a Military Scheduling Problem*, Naval Postgraduate School Technical Report, NPS-OR-01-010, August 2001.

PRESENTATIONS:

Gaver, D.P., Glazebrook, K.D., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," XXI International Seminar on Stability Problems for Stochastic Models, Eger, Hungary, 28 January-3 February 2001.

Gaver, D.P., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Gaver, D.P., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," MIT Lincoln Laboratory, 16 July 2001.

Gaver, D.P., Jacobs, P.A. and Pilnick, S.E., "Hybrid Approaches to Agent-Based Complex Adaptive Systems," MOVES Open House, 30 August 2001.

Gaver, D.P., Jacobs, P.A. and Pilnick, S.E., "Some Thesis Research Topics in Stochastic/Probabilistic OR," Presentation to MV4900, 6 December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: General Assignment Program, Generic Algorithms, Generalized Generalized Assignment Problem, GAP, GGAP

JOINT EXPERIMENTATION HIGH-LEVEL LOW-RESOLUTION MODELING

Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Steven E. Pilnick, Senior Lecturer
Wayne E. Meyer Institute of Systems Engineering
Sponsor: U.S. Joint Forces Command and the Naval Postgraduate School

OBJECTIVE: Purpose of the research is to formulate and study state space models for information operations in joint warfare with a view towards guiding allocation of acquisition and eventually operational resources. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems on interactive and joint conflicts

SUMMARY: High-level-low-resolution models for the study of the Common Relevant Operational Picture (CROP) have been formulated, studied and used to provide insight on the benefits of the CROP.

PUBLICATIONS:

Gaver, D.P. and Jacobs, P.A., "A Model for Analyzing Blue Force Response to Region Invasion by Multi-Type Red Forces," forthcoming.

Barkdoll, T.C., Gaver, D.P., Glazebrook, K.D., Jacobs, P.A. and Posadas, S., "Suppression of Enemy Air Defenses (SEAD) as an Information Duel," to appear in *Naval Research Logistics.*

DoD KEY TECHNOLOGY AREAS: Human-System Interface, Modeling and Simulation

KEYWORDS: Combat Models, Bayesian Perception Updating, Decision Analysis

MODELS FOR LIVER INSULT AND RECOVERY

Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: Naval Health Research Center Detachment – Toxicology

OBJECTIVE: Use mathematical computer-based modeling and statistical methods to quantify the effects of a toxin on the liver.

SUMMARY: Mechanistic models for the effect of a toxic substance on the liver have been developed and experimental data have been analyzed.

CONFERENCE PRESENTATIONS:

Gaver, D.P., Jacobs, P.A., Carpenter, R.L., Robinson, P. and Bobb, A., "Towards a Model of Liver Insult and Recovery After Insult by Xenobiotic Chemicals," Poster Session, 40th Annual Meeting, Society of Toxicology, San Francisco, CA, 24–29 March 2001.

OTHER:

Carpenter, R.L., Gaver, D.P., Jacobs, P.A., Narayanan, T.K., Jung, A. and Bobb, A., "A Mechanistic Mathematical Models of Cell Toxicity from APAP," forthcoming.

Carpenter, R.L., Gaver, D.P., Jacobs, P.A., Robinson, P. and Bobb, A., "Towards a Model of Liver Insult and Recovery After Insult by Xenobiotic Chemicals," forthcoming.

Bobb, A., Carpenter, R.L., Gaver, D.P. and Jacobs, P.A., "High Dosage Model for the Effect of APAP on Liver Cells," forthcoming.

DoD KEY TECHNOLOGY AREAS: Biomedical, Human Systems Interface, Environmental Quality

KEYWORDS: PBPK/PD Compartment Modeling, Predictive Toxicology

TRAINING AND RESEARCH SUPPORT FOR DIRECTOR, OPERATIONAL TEST AND EVALUATION

Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsors: Director, Operational Test and Evaluation, U.S. Army Analysis Command, U.S. Army Training Analysis Command-Monterey and Naval Postgraduate School

OBJECTIVE: Purpose of the research is to develop training and reference material on a Web site and new methodology for operational testing which emphasizes modeling and simulation.

SUMMARY: Models for sequential stage system reliability growth via failure model removal have been formulated and studied. Models to assess the operational suitability of a platoon of advanced amphibious assault vehicles (AAAVs) have been formulated and studied. Materials for an operational test and evaluation Web site have been developed.

PUBLICATIONS:

Gaver, D.P., Jacobs, P.A. and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution," *Safety & Reliability: ESREL 2001 Towards a Safer World,* Zio, E., Demichela, M., Piccinini, N., (eds.), Politecnico di Torino, Vol. 2, pp. 1109-1116, 2001.

Gaver, D.P, Jacobs, P.A. and Kemp, J., *Modeling the Operation of a Platoon of Amphibious Vehicles for Support of Operational Test and Evaluation (OT&E)*, Naval Postgraduate School Technical Report, NPS-OR-01-009, July 2001.

Gaver, D.P., Jacobs, P.A. and Seglie, E., *Stochastic Models for Promoting and Testing System Reliability Evolution*, Naval Postgraduate School Technical Report, NPS-OR-01-011, September 2001.

PRESENTATIONS:

Gaver, D.P., Jacobs, P.A and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution," European Safety and Reliability Conference, Turino, Italy, 16-20 September 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, University of California at Davis, 22 February 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, Oregon State University, 26 February 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, Birmingham University, 28 September 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, University of Oslo, 5 October 2001.

THESES DIRECTED:

Lintz, G., "Analysis of Reliability and Life Data for AN/ASS-44(V) Forward Looking Infrared System to Forecast H-60 Operational Availability," Masters Thesis, Naval Postgraduate School, September 2001.

Kemp. J., "Modeling and Simulation in Support of Operational Test and Evaluation for the Advanced Amphibious Assault Vehicle," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Bullock, G., "Delphi Software Implementation of Model for System Survival Probability," January 2001.

Bullock, G., "Delphi Software Implementation of Model for Sustainability of a Platoon of Amphibious Vehicles," June 2001.

Gaver, D.P., "Operational Test and Evaluation," Web Site: http://www.nps.navy.mil/opnsrsch/testeval/

DoD KEY TECHNOLOGY AREAS: Human-Systems Interface, Modeling and Simulation

KEYWORDS: Military Test and Evaluation, Statistical Data Analysis, Decision Analysis, Modeling and Simulation

DEVELOPMENT OF JOINT EXPERIMENTATION METHODOLOGY, HANDBOOK AND COURSEWARE

Thomas H. Hoivik, Senior Lecturer
Department of Operations Research
Sponsor: U.S. Joint Forces Command

OBJECTIVE: To develop a step-by-step joint experimentation planning and design methodology for U.S Joint Forces Command to use for planning and analysis of major Joint Experiments.

SUMMARY: Joint Experiments present a great opportunity for experimenting with new initiatives, which may include a variety of concepts, processes, or systems (CPS). However, there are mixed opinions about the value and validity of knowledge obtained during these past complex experiments. As a result, U.S. Joint Forces Command (J9) requested guidance on how to better plan, conduct and analyze complex joint experiments including the development of an experimentation handbook and courseware for training of participants. The research investigated and developed a detailed joint experimentation methodology including methods for identifying and fully defining concept, process or system issues and evaluation measures to gain insight into initiative effectiveness. The joint experimentation handbook and courseware introduced tools and techniques for better analysis, utilizing workshops, simulations and limited objective experiments, before large-scale wargames and complex joint and service experiments are conducted. The handbook will be used as a base reference and guide for future joint experimentation.

PUBLICATIONS:

Hoivik, T.H., "Fundamental of Joint Experimentation Planning and Design," U.S. Joint Forces Command (J9) Report, February 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Joint Experimentation, Joint Forces Command, Joint Warfare

JOINT INTEROPERABILITY TESTING OF THEATER MISSILE DEFENSE SYSTEMS: LAUNCH POINT ESTIMATION AND IMPACT POINT PREDICTION

Robert A. Koyak, Assistant Professor
Department of Operations Research
Robert G. Hutchins, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Defense Information Systems Agency, Joint Interoperability Test Command

OBJECTIVE: To characterize in physical and statistical terms the launch points and impact points of ballistic missiles detected during flight, and to use these results to develop criteria for joint interoperability testing of sensor platforms engaged in joint air and space surveillance.

SUMMARY: The investigation considered how tracking information that is communicated between sensor platforms during joint air and space surveillance exercises can be used to test the validity of reported missile launch points and impact points. The extent of this information is limited due to bandwidth constraints. Inaccurate estimates of launch and impact points, and inconsistent methodologies between sensor platforms, result in a disruptive common air picture that impairs interoperability. Much of the uncertainty in these quantities derives from unknown characteristics of the missile (e.g., the ballistic coefficient) that are difficult to estimate under practical tracking conditions. Using simulation and statistical theory, the investigation succeeded in developing criteria that can be used for interoperability testing purposes. Research on this project has continued into CY 2002.

PUBLICATIONS:

Herrin, R.R., Barrett, N.L., Baker, B.G. and Koyak, R.A., "Joint Theater Air and Missile Defense Interoperability Testing Capabilities and Challenges," *ITEA Journal of Test and Evaluation*, Vol. 22, pp. 31–40, June/July 2001.

Koyak, R.A. and Hutchins, G.R., "Joint Interoperability Testing of Theater Missile Defense Systems: Launch Point Estimation and Impact Point Prediction," Technical Report, submitted to the Joint Interoperability Test Command (draft).

THESIS DIRECTED:

Leffers, J.W., "Statistical Validation of Track Quality Numbers for Joint Interoperability Testing of Theater Air and Missile Defense Families of Systems," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Sensors

KEYWORDS: Missile, Sensor, Tracking, Surveillance

EXPLORING ANALYSIS OF COMBAT DATA

Thomas W. Lucas, Associate Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: Attempt to validate models and look for invariant trends in data sets on historical battles.

SUMMARY: This research explores the validation of Lanchester equations as models of the attrition process for the Battle of Kursk in World War II. The methodology and results of this study extend previous validation efforts undertaken since the development of the Ardennes Campaign Simulation Data Base (ACSDB) in 1989 and the Kursk Data Base (KDB) in 1996. The KDB is a computerized database developed by the Dupuy Institute and the Center for Army Analysis from military archives in Germany and Russia. The data are two-sided, time-phased (daily), highly detailed, and encompass 15 days of the campaign. Also, CAA's CDB90G data set, which contains about 140 attributes on nearly 660 land battles

is being used to see what factors, over time, are associated with victory. Using classification trees, it was found that objective variables, by themselves, cannot explain the outcome of battles. Relative factors, such as leadership, have deep impacts on success. The classification models also reveal that the factors affecting battle outcomes have changed over time. A leadership advantage played an important role for hundreds of years. However, in the 20th century, air sorties, tanks, and intelligence showed a higher importance.

PUBLICATIONS:

Lucas, T. and Turkes, T., "Fitting Lanchester Equations to the Battle of Kursk," submitted to *Naval Research Logistics*, 2001.

THESIS DIRECTED:

Coban, M., "Predicting Battle Outcomes With Classification Trees," Masters Thesis, Naval Postgraduate School, December 2001.

Dinges, J., "Exploring the Validation of Lanchester Equations for the Battle of Kursk," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling and Simulation, Combat Analysis

CNET: PHASE III

David H. Olwell, Senior Lecturer
Department of Operations Research
Sponsor: Chief of Naval Education and Training

OBJECTIVE: Modify the Web-based content for OS2100 and deliver to NAVSEA using a mixture of instructional means.

SUMMARY: OS2100 has been previously prepared for Web-based delivery. In fall quarter, an opportunity arose to test the Web materials and simultaneously deliver the OS2100 course to four NAVSEA sites, using a mixture of on-site, video-teleconference, and web delivery methods. The materials were modified and the course was delivered. Student input indicates on-site instruction is preferred, that a mixture of modalities (Web, video, and on-site) is acceptable, and the Web-only is the last preference. Students whose duties resulted in travel during class periods depended on the Web materials to stay current, and many would not have completed the class without those materials being available. Different students had different learning styles, which resulted in differential use rates for the various course components. The lessons learned will be prepared in 2002 and disseminated.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Distributed Learning, Web-Based Learning, Distance Learning

OPTIMIZATION MODELING IN SUPPORT OF TANKER REQUIREMENTS STUDY FOR 2005 (TRS-05)

Richard E. Rosenthal, Professor
Laura M. Williams, Research Assistant Professor
Department of Operations Research
LtCol Steven F. Baker, Associate Professor, U.S. Air Force Academy
Sponsor: Office of Secretary of Defense, Program Analysis and Evaluation

OBJECTIVE: To determine the number tanker airframes and aircrews needed to support the air mobility function in the years 2005 and beyond.

SUMMARY: Evaluation of tanker usage as well as overall system performance in the Weapons of Mass Destruction case has been completed. This analysis included excursions designed to analyze the effects of limited tanker forces, use of C130 aircraft as intra-theater shuttles, effects of limited fuel and airfield capacities. The analysis of tanker support for fighter drags is in progress. Model modifications and data analysis to support the fighter drag analysis is complete. The results of the fighter drag analysis are currently being validated with the help of Air Mobility Command personnel.

PUBLICATIONS:

Baker, S., Morton, D., Rosenthal, R. and Williams, L., "Optimizing Military Airlift, 2000," to appear in *Operations Research*, 2002.

Baker, S.F., Rosenthal, R. and Williams, L., *Tanker Requirements Study 2005: The Impact of Weapons of Mass Destruction Attack On Airlift Throughput*, Technical Report, Naval Postgraduate School.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Air Mobility, Aerial Refueling, Tankers, Mobilization

ADAPTIVE EXPLORATION OF AGENT-BASED COMMAND AND CONTROL SIMULATIONS

Susan Sanchez, Professor
Thomas W. Lucas, Associate Professor
Department of Operations Research
Sponsor: U.S. Marine Corps Combat Development Command

OBJECTIVE: Develop a framework that facilitates high-dimensional explorations of Agent-Based Command and Control Simulations.

SUMMARY: Analysts use combat models to provide information to decision-makers who must make and justify decisions involving billions of dollars and impacting many lives. Insights from combat models should be based on an ensemble of outcomes. This research helps build the foundation for a multi-year effort to define, test, and implement a new set of high-dimensional search strategies algorithms for use in exploring agent-based simulations. The prototype approaches that were developed automatically look across a breadth of factors and adaptively focus sampling efforts on the "interesting" effects and interactions. The efficiency of the search strategies under a variety of scenarios is being examined with computational experiments. These experiments are being conducted on known surfaces, using a stochastic response surface generator, and existing distillations.

PUBLICATIONS:

Lucas, T., Sanchez, S., Brown, L. and Vinyard, W., "Better Designs for High-Dimensional Explorations of Distillations," to appear in *Maneuver Warfare Science 2002*, Marine Corps Combat Development Command, Defense Automated Printing Service, 2002.

Sanchez, S.M. and Lucas, T., "Agent-based Simulations: Simple Models, Complex Analyses," Invited paper to appear in *Proceedings of the 2002 Winter Simulation Conference*, Snowdon, J.L., Charnes, J., Chen, C-H and Yucesan, E. (eds.), Institute of Electrical and Electronic Engineers, Piscataway, NJ, 2002.

PRESENTATIONS:

Lucas, T.W. and Sanchez, S.M., "Adaptive High-Dimensional Explorations of Agent-based Command and Control Simulations,"11/01 – INFORMS, Miami, FL, November 2001.

Sanchez, S.M. and Lucas, T.W., "Exploring Agent-based Simulations: Simple Models, Complex Analyses," 11/01 – INFORMS, Miami, FL, November 2001.

Sanchez, S.M. and Lucas, T.W., "Adaptive Exploration of Project Albert Distillations," INFORMS International, Maui, HI, June 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Agent-Based Command and Control Simulations," INFORMS Military Applications Society 4th Annual International Meeting, Quantico, VA, May 2001.

THESIS DIRECTED:

Ho, K.J., "An Analysis of Distributed Combat Systems," Masters Thesis, Naval Postgraduate School, December 2001.

Vinyard, W.C., "Reducing Non-monotonicities in Combat Models," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Vinyard, B. and Lucas, T., "Exploring Combat Models for Non-monotonicities and Remedies," submitted to *PHALANX*.

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

KEYWORDS: Modeling and Simulation, Design of Experiments, Agent-based Models, Command, Control and Communications

CNET: PHASE III

Susan Sanchez, Professor
Department of Operations Research
Sponsor: Chief of Naval Education and Training

OBJECTIVE: Adapt the interactive computer cases and games to be used in a web-based course on operations analysis. Specifically, the goals were to make the modules for this Web-based course more user friendly, and to change the contexts from generic routing and distribution problems to military applications. This is a continuation of CNET: OPERATIONS ANALYSIS.

SUMMARY: Three software modules were added to the course materials for OS3000: Introduction to Management Science for Information Systems and Operations (ISO). Instructions for student assignments were written, and related topics were integrated into questions for the course's weekly web discussion board. The first module is an agent-based simulation that introduces the students to some basic concepts in simulation and experimental design by allowing them to investigate the efficacy of different command and control structures on a peacekeeping operation. The second module introduces the students to inventory control, and the impact that various ordering policies, lead times, and demand distributions have on both

total costs and the fill-rate. The third module motivates the use of shortest-path and min-low/max-cut problems for network interdiction. The basic software tools, instructions, and assignments were put in place during Fall 2001. Graphics enhancements continued through Winter 2002.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Distributed Learning, Web-Based Learning, Distance Learning

DISTRIBUTED LEARNING: OPERATIONS ANALYSIS

Susan Sanchez, Professor
Department of Operations Research
Sponsor: Chief of Naval Education and Training

OBJECTIVE: Develop a framework for a case-oriented management science course for the ISO curriculum. Web-based elements of the course should both (1) form the basis for a high-quality, relevant distributed learning course for non-resident ISO students, and (2) enhance the learning experience for resident ISO students.

SUMMARY: The structure for online course delivery was put in place for OS3000: Introduction to Management Science for Information Systems and Operations (ISO). The course was offered as a web-enhanced course to resident students at NPS during Spring 01. Interactive java applets and computer games were used to illustrate the quantitative modeling framework for a variety of topics, such as inventory management, resource allocation, routing, scheduling, network interdiction, and network reliability. Web-based courseware distributed software, slides, and other course content, while Web discussion boards provided a forum for instructor-learner and learner-learner interactions. The team-based course structure provided the students with hands-on experience in defining problems, developing appropriate quantitative models, defending their model choices, and effectively communicating the results. Military examples were used to motivate the material, and ties to examples and scenarios from previous ISO coursework were put in place. Student teams were also responsible for preparing briefings on recent ISO applications that used tools related to those covered in class. Course development continued in CNET Phase III.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Distributed Learning, Web-Based Learning, Distance Learning

ECONOMIC BENEFIT OF NAVAL FORWARD PRESENCE

David A. Schrady, Distinguished Professor
Department of Operations Research
R.L. Looney, Professor
Douglas Porch, Professor
Department of National Security Affairs
Sponsor: Chief of Naval Operation (N81)

OBJECTIVES: To develop an integrated framework for assessing the consequences of globalization on the market forces associated with naval forward presence and crisis response. This task will draw heavily on the expanding literature on globalization, integrating it with our quantitative findings on economic benefits.

SUMMARY: This study develops an integrated framework for assessing the consequences of globalization on the market forces likely to be affected by naval forward presence and crisis response. The study demonstrates that it is possible to develop an operational definition for quantifying globalization. The study found a clear linkage between the highly globalized countries and the manner in which oil shocks affect their economies. Over time, highly globalized countries including the United States have become more vulnerable to oil price shocks. Because naval forward presence and crisis response tends to suppress

oil shocks and return prices to their equilibrium levels, the role of naval activities in economic stabilization has not only taken on increased importance in recent years but, with the likely continuation of global trends, should play an even greater positive economic role for the United States in the foreseeable future.

PUBLICATONS:

Looney, R.E., Schrady, D.A., et al., "Estimating Economic Benefits of Naval Forward Presence: A Brief Summary," *Proceedings of Conference on Globalization and Naval Forward Presence*, Ch. 3, Institute for National Security Studies, National Defense University, Washington, DC, 19 April 2001.

Looney, R E., Schrady, D.A. and Brown, R.L., "Estimating the Economic Benefits of Forward-Engaged Naval Forces," *Interfaces*, Vol. 31, No. 4, July-August 2001.

Looney, R.E., Schrady, D.A. and Porch, D., *Economic Impact of Naval Forward Presence: Benefits, Linkage and Future Prospects as Modified by Trends in Globalization*, Naval Postgraduate School Technical Report, NPS-NSOR-02-001, December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Naval Forward Presence, Economic Benefits, Econometrics, Globalization

MODELING AND SIMULATION ANALYSIS FOR EXPEDITIONARY LOGISTICS

David A. Schrady, Distinguished Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVES: The objective is to support Metron, Inc. and Lockheed Martin who, separately, hold contracts for modeling and simulation of expeditionary logistics in support of the Future Naval Capabilities program of the Office of Naval Research.

SUMMARY: The effort has consisted of support and analyses defining and documenting logistics command and control, modeling and simulation, database, planning, and user interface requirements responsive to the ONR Future Naval Capabilities Expeditionary Logistics vision. It has further involved determination of the logistics representation enhancements needed in the Naval Simulation System in order to meet these requirements. Monthly activity reports were provided to both contractors for inclusion in their monthly reports to ONR.

PRESENTATION:

Schrady, D.A., "Combat Logistics," Commander Naval Forces Korea, Commanders Conference, Port Hueneme, CA, 10 February 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Sustainability, Sea-Based Logistics, Expeditionary Logistics, Expeditionary Maneuver Warfare

RESEARCH ON AGGREGATED COMBAT MODELS II – METHODOLOGY FOR THE COMPARATIVE EVALUATION OF MODELS

James G. Taylor, Professor
Department of Operations Research
Sponsor: United States Army – Dismounted Battlespace Battle Lab (DBBL)

OBJECTIVE: To improve quantitative methodology for assisting in the selection of aggregated-force combat models and submodels, particularly for the attrition process. Also, to improve attrition methodologies for such models.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Combat Models, Evaluation of Combat Models, Attrition Methodologies

SUPPORT OF JCATS LIMITED V&V

James G. Taylor, Professor
Department of Operations Research
Sponsor: United States Army – Dismounted Battlespace Battle Lab (DBBL)

OBJECTIVE: Assist in the conduct of a limited verification and validation (V&V) of the non-lethal capabilities of the joint conflict and tactical simulation (JCATS). Primary attention is to be given to the verification of JCATS algorithms, particularly those for simulating the capabilities of non-lethal weapons (NLW).

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Model Verification/Validation, Non-Lethal Effects, Simulation of Joint Warfare

SUPPORT OF PA&E CAMPAIGN MODEL PROGRAM (PAEP) (UPGRADING GROUND-COMBAT ATTRITION AND MOVEMENT AND IMPROVING TREATMENT OF UNCERTAINTIES

James G. Taylor, Professor
Department of Operations Research
Sponsor: Office of the Secretary of Defense

OBJECTIVE: Provide support for upgrading the PA&E campaign model program (PAEP) with the addition of a ground-force model (that is consistent with overall PAEP goals) and also for improving the treatment of uncertainties.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Weapons Scoring/Aggression, Ground-Combat Attrition, Ground-Force Movement

UPGRADING GROUND-COMBAT ATTRITION AND MOVEMENT FOR ITEM

James G. Taylor, Professor
Department of Operations Research
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: Work closely with time developer (SAIC) to improve assessment algorithm for direct-fire ground-combat attrition in item. The new single-weapon-system-type kill rates recently developed by the proposed principal investigator would be basis with this upgrade.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Stand-Alone Attrition Methodol, Lanchester Attrition-Rate COEF, Direct-Fire Ground-Combat ATTR, Indirect-Fire Ground-Combat AT

LP/POMDP INFORMATION OPTIMIZATION METHODOLOGY

Alan Washburn, Professor
Department of Operations Research
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Develop and test an optimization method for jointly assigning sensor assets and firepower assets to a target set. The method will employ Linear Programming and Partially Observable Markiov Decision Processes to generate policies for joint, sequential assignments.

SUMMARY: Current theory is extended to include the effects of surveillance, as well as the effects of BDA (bomb damage assessment). A computer program JOIST has been produced that achieves solutions in minutes to hours for realistically scaled problems, depending on desired accuracy. The scenario considered by JOIST is one where sorties must be assigned to targets in an environment where information about the effects of strikes is expensive and imperfect, and where one effect of a sortie may be to discover new, previously unknown targets. Expected total target value killed is maximized while constraints on the availability of sorties and acceptable attrition are observed. The methodology is suitable for investigating the relative benefits of information and strike assets, and possibly for helping to construct air tasking orders. Efforts in the second year (2002) will be devoted to improving efficiency, and to transitioning JOIST to practical purposes.

PUBLICATIONS:

Washburn, A., *JOIST: Joint Optimizing Informational Strike Tool*, Naval Postgraduate School Project Report, NPS-OR-02-001-PR, 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: BDA, POMDP, Information

C130 TRAINING MODEL

Laura M. Williams, Research Assistant Professor
Department of Operations Research
Sponsor: 314th Airlift Wing, Little Rock Air Force Base

OBJECTIVE: The primary objective of this project is to provide a model, i.e., an automated tool, to create operational aircrew training schedules of varying time horizons for individual crewmembers in a variety of syllabi.

SUMMARY: The primary scheduling model, a set of mixed-integer programs designed to create good schedules in a reasonable amount of time, has been completed and is currently being thoroughly tested. Documentation and programming of a user interface are in progress. The user interface, joint work with the sponsor, is being designed to take advantage of the user's current data environment to make the model as easy as possible to use on a regular basis.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Scheduling, Training

LARGE-SCALE MIXED INTEGER PROGRAMMING

R. Kevin Wood, Professor
Department of Operations Research
Sponsor: Joint Warfare Analysis Center

OBJECTIVE: Develop integer-programming methods, including decomposition, for solving interdiction problems under uncertainty.

SUMMARY: Available from sponsor.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

SUPPORT FOR REAL-TIME EXECUTION DECISION SUPPORT (REDS)

R. Kevin Wood, Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Provide technical support for the strike-planning and execution system (REDS, Real-time Execution Decision Support) being developed as the Space and Naval Warfare Systems Command, San Diego. Areas of interest include predicting locations of mobile targets, optimization of aircraft-to-target assignments and route planning.

SUMMARY: Potential techniques for predicting locations of mobile targets were explored. For purposes of familiarization, the PI visited Fallon Naval Air Station to observe how element-level strike planning is currently carried out; the execution of the planned strike was also observed.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

SUPPORT FOR THE CENTER FOR OPERATIONS RESEARCH, NATIONAL SECURITY AGENCY

R. Kevin Wood, Professor
Department of Operations Research
Sponsor: National Security Agency

OBJECTIVE: Provide on-call analytical support to the National Security Agency.

SUMMARY: Available from sponsor.

THESES DIRECTED:

Bingol, L., "A Lagrangian Heuristic for Solving a Network Interdiction Problem," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

DEPARTMENT OF OPERATIONS RESEARCH

2001
Faculty Publications and Presentations

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Brown, G., Keegan, J., Vigus, B., and Wood, K., "The Kellogg Company Optimizes Production, Inventory, and Distribution," *Interfaces*, Vol. 31, pp. 1-15, 2001.

Herrin, R.R., Barrett, N.L., Baker, B.G., and Koyak, R.A., "Joint Theater Air and Missile Defense Interoperability Testing Capabilities and Challenges," *ITEA Journal of Test and Evaluation*, Vol. 22, pp. 31–40, June/July 2001.

Hohzaki, R. and Washburn, A., "The Diesel Submarine Flaming Datum Problem," *Military Operations Research*, Vol. 6, No. 4, pp. 19-30, 2001.

Looney, R.E., Schrady, D.A. and Brown, R.L., "Estimating the Economic Benefits of Forward-Engaged Naval Forces," *Interfaces*, Vol. 31, No. 4, July-August 2001.

Marín, A. and Salmerón, J., "A Risk Function for the Stochastic Modeling of Electric Capacity Expansion," *Naval Research Logistics*, Vol. 48, pp. 662-683, 2001.

Schrady, D.A., "Golden Anniversary (of the NPS OR Program)," *ORMS Today*, Vol. 28, No. 1, February 2001.

Washburn, A., "A New Kind of Fictitious Play," *Naval Research Logistics*, Vol. 48, pp. 270-280. 2001.

Washburn, A., "Bits, Bangs, or Bucks? The Coming Information Crisis," *PHALANX*, Vol. 34, No. 3 (part I) and No. 4 (part II), 2001.

CONFERENCE PAPERS

Buttrey, S.E., Nolan, D. and Temple Lang, D., "An Environment for Creating Interactive Statistical Documents," *Proceedings of the 33rd Symposium on the Interface of Computing Science and Statistics*, Costa Mesa, CA, 13-16 June 2001.

Looney, R.E. and Schrady, D.A., et al., "Estimating Economic Benefits of Naval Forward Presence: A Brief Summary," *Proceedings of Conference on Globalization and Naval Forward Presence*, Ch. 3, Institute for National Security Studies, National Defense University, Washington D.C., 19 April 2001.

Marín, A. and Salmerón, J., "Modelización Conjunta para la Locacización de Facilidades y Expansión de Capacidad," *Annals of the JAIIO*, edited by SADIO, Vol. 30, pp. 94-101, Buenos Aires, Argentina, 2001.

Sanchez, S.M., "ABC's of Output Analysis," *Proceedings of the 2001 Winter Simulation Conference*, Peters, B.A., Smith, J.S., Medeiros, D.J. and Rohrer, M.W. (eds.), pp. 30-39. Institute of Electrical and Electronics Engineers, Piscataway, NJ, 2001.

Sanchez, S.M. and Hynes, G.E., "Perception and Assessment of Online Communication Skill Acquisition," *Proceedings of the Fall 2001 Symposium on Assessing Online Instruction*, Monterey, CA, October 2001.

CONFERENCE PRESENTATIONS

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G., "M&S in Classroom Instruction and Thesis Research at the Naval Postgraduate School," NAVMSMO Technical Interchange Meeting, National Defense University, Ft. McNair, Washington, DC, 23 August 2001.

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Brown, G., Byrne, P. and Washburn, A., "The Fast Theater Model," 69th Military Operations Research Symposium, U. S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G., Newman, A.M., Rosenthal, R.E and Rowe, A.A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Tarantino, W.J., "Optimal Stationing of Army Forces," National Meeting of the Institute for Operations Research and the Management Sciences, Miami, FL, 4-7 November 2001.

Dell, R.F. and Noble, J.D., "Scheduling and Distributing Intra-Theatre Wartime POL Requirements," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Brown, G.G., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Gaver, D.P., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Gaver, D.P., Glazebrook, K.D., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," XXI International Seminar on Stability Problems for Stochastic Models, Eger, Hungary 28 January–3 February 2001.

Gaver, D.P., Jacobs, P.A. and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution" European Safety and Reliability Conference, Turino, Italy, 16-20 September 2001.

Gaver, D.P., Jacobs, P.A., Carpenter, R.L., Robinson, P. and Bobb, A., "Towards a Model of Liver Insult and Recovery After Insult by Xenobiotic Chemicals," Poster Session, 40th Annual Meeting, Society of Toxicology, San Francisco, CA, 24–29 March 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Agent-Based Command and Control Simulations INFORMS Military Applications Society 4th Annual International Meeting, Quantico, VA, May 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Command and Control Simulations," Military Applications Society 4th Annual Meeting, Quantico, VA, 21-23 May 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Project Albert Distillations," INFORMS International 2001, Maui, HI, 17-20 June 2001.

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Lucas, T.W. and Sanchez, S.M., "Exploring Agent-based Simulations: Simple Models, Complex Analyses," 11/01 – INFORMS, Miami, FL, November 2001.

Morton, D., Salmerón, J. and Wood, K., "A Sampling-Based Cutting-Plane Method for Stochastic Programming," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Morton, D., Salmerón, J. and Wood, K., "A Stochastic Program for Optimizing Military Sealift subject to Attack," Workshop on Decision-Making Under Uncertainty, Molde, Norway, 18-20 May 2001.

Morton, D., Salmerón, J. and Wood, K., "Optimizing Military Sealift Subject to Attack," INFORMS National Meeting, Miami Beach, FL, 4-7 November 2001.

Sanchez, S.M. and Lucas, T.W., "Adaptive Exploration of Project Albert Distillations," INFORMS International, Maui, HI, June 2001.

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Sanchez, S.M. and Lucas, T.W., "Exploring Agent-Based Simulations: Simple Models, Complex Analyses," INFORMS National Meeting, Miami, FL, 4-7 November 2001.

Sanchez, S.M. and Wood, R.K., "Solving Stochastic Network Interdiction Problems with the Partially Enumerate then Screen Method," INFORMS International 2001, Maui, HI, 17-20 June 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Schrady, D.A., "Combat Logistics," Commander Naval Forces Korea, Commanders Conference, Port Hueneme, CA, 10 February 2001.
Tarantino, W.J, Dell, R.F. and Connor, G., "Optimal Stationing of Army Forces (OSAF)," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Wood, R.K. and Sanchez, S.M., "Solving Stochastic Network Interdiction with the BEST Algorithm," AFOSR PI Meeting, Minnowbrook, NY, 2001.

TECHNICAL REPORTS

Baker, S.F., Rosenthal, R.E. and Williams, L., *Tanker Requirements Study 2005: The Impact of Weapons of Mass Destruction Attack on Airlift Throughput*, Naval Postgraduate School Technical Report, June 2001.

Brown, G.G., Newman, A.M, Rosenthal, R.E. and Rowe, A.A., *Optimizing Tomahawk Strikes*, Naval Postgraduate School Technical Report, NPS-OR-01-001-PR, January 2001, (also appeared in *Naval Postgraduate School Research Newsletter*).

Gates, W. and Washburn, A., *The Navy Operational Support Aircraft Fleet*, Naval Postgraduate School Technical Report, NPS-OR-01-006-PR, 2001.

Gaver, D.P, Jacobs, P.A. and Kemp, J., *Modeling the Operation of a Platoon of Amphibious Vehicles for Support of Operational Test and Evaluation (OT&E)*, Naval Postgraduate School Technical Report, NPS-OR-01-009, July 2001.

Gaver, D.P., Jacobs, P.A., and Seglie, E., *Stochastic Models for Promoting and Testing System Reliability Evolution*, Naval Postgraduate School Technical Report, NPS-OR-01-011, September 2001.

Glazebrook, K.D., Gaver, D.P., and Jacobs, P.A., *On a Military Scheduling Problem*, Naval Postgraduate Technical Report, NPS-OR-01-010, August 2001.

Looney, R.E, Schrady, D.A. and Porch, D., *Economic Impact of Naval Forward Presence: Benefits, Linkage and Future Prospects as Modified by Trends in Globalization*, Naval Postgraduate School Technical Report, NPS-NS-02-001, December 2001.

Washburn, A., *JOIST: Joint Optimizing Informational Strike Tool*, Naval Postgraduate Technical Report, NPS-OR-02-001-PR, 2001.

Washburn, A., *The Fast Theater Model (FATHM)*, Naval Postgraduate School Technical Report, NPS-OR-01-002-PR, 2001.

CONTRIBUTION TO BOOK

Gaver, D.P., Jacobs, P.A., and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution," *Safety & Reliability: ESREL 2001 Towards a Safer World*, E. Zio, M. Demichela, N. (eds.), Piccinini, Politecnico di Torino, Vol. 2, pp. 1109-1116, 2001.

OTHER

Bullock, G., "Delphi Software Implementation of Model for System Survival Probability," January 2001.

Bullock, G., "Delphi Software Implementation of Model for Sustainability of a Platoon of Amphibious Vehicles," June 2001.

Gaver, D.P., "Operational Test and Evaluation," Web Site: http://www.nps.navy.mil/opnsrsch/testeval/

GRADUATE SCHOOL OF ENGINEERING AND APPLIED SCIENCES

RUDOLF PANHOLZER
DEAN

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

MAX PLATZER
CHAIR

AERONAUTICS AND ASTRONAUTICS

OVERVIEW:

The Department of Aeronautics and Astronautics is an integral part of the Graduate School of Engineering and Applied Sciences. Aero/Astro faculty members conduct research and teach courses covering air and space vehicles, missiles, propulsion, aerodynamics, avionics, control systems, structures, turbomachinery, computational and experimental methods, orbital mechanics and combat survivability that emphasize total systems design. The uniqueness of this approach is that air and space vehicles are considered part of a larger combat system that includes all aspects of warfighting.

Navy and Marine Corps aircraft are designed to operate abroad ships as part of a larger battlegroup. Challenges normally not considered by aircraft operating from land bases become design constraints for shipboard compatibility. By working in a Total System Design Group, Aero/Astro faculty and students are exposed to the constraints of shipbuilding, software development and weapons compatibility. Additional issues such as acquisition methods, analysis of alternatives, and order of battle scenarios can be explored by working with the Graduate School of Business and Public Policy, the Graduate School of Operations and Information Sciences, and the School of International Graduate Studies. Aero/Astro faculty and students are exposed to a wide variety of disciplines to develop capable runway-independent aircraft and robust space systems.

CURRICULA SERVED:

- Aeronautical Engineering (Curriculum 610)
- Engineering/Avionics (Curriculum 611)
- NPS-TPS Cooperative Program (Curriculum 612)
- Space Systems Engineering (Curriculum 591)

DEGREES GRANTED:

- Master of Science in Aeronautical Engineering
- Master of Science in Engineering Science
- Master of Science in Astronautical Engineering
- Aeronautical and Astronautical Engineer
- Doctor of Engineering

RESEARCH THRUSTS:

- Aerospace Vehicle Design
- Aerodynamics, Aeroelasticity, V/STOL Aircraft Technology
- Flight Mechanics and Controls
- Structures, Structural Dynamics, Composite Mechanics, Fracture and Fatigue
- Propulsion and Gas Dynamics
- Avionics
- Rotary Wing Aircraft Technology
- Aircraft Combat Survivability
- Spacecraft Systems, Attitude Control and Smart Structures
- Spacecraft Guidance, Control and Optimization

RESEARCH FACILITIES:

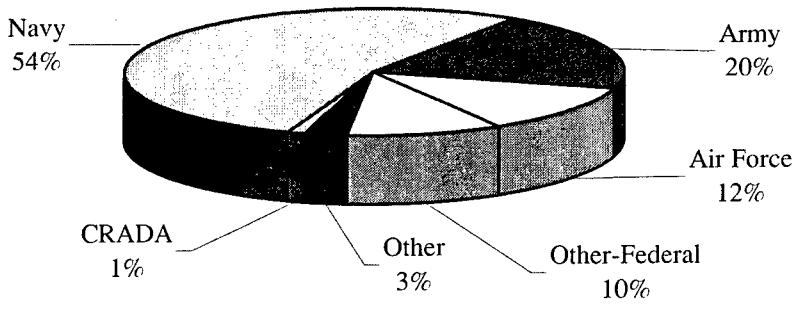
- Aeronautical Engineering Laboratories:
  - Aerodynamics Laboratory
  - Gas Dynamics Laboratory
  - Combustion Laboratory
  - Turbo-Propulsion Laboratory
  - Computation Laboratory
  - Flight Mechanics Laboratory
  - Structures and Composite Laboratory
  - Controls Laboratory
  - Avionics Laboratory
  - Survivability and Lethality Assessment Laboratory
  - Rotorcraft Laboratory
  - Aeronautics Design Laboratory
- Spacecraft Laboratories:
  - FLTSATCOM Laboratory
  - Spacecraft Test Laboratory
  - Spacecraft Attitude Dynamics Laboratory
  - Spacecraft Design Laboratory

RESEARCH CENTERS:

- Navy-NASA Joint Institute of Aeronautics
- Spacecraft Research and Design Center
- Turbo-Propulsion Laboratory
- Vertical Flight Technology Center
- Aerodynamics Decelerator Systems Center

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 Aeronautics and Astronautics is provided below:



Size of Program: $2861K

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SPACECRAFT SYSTEMS

Brij N. Agrawal, Professor
Department of Aeronautics and Astronautics
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The goal of this project is to develop and operate spacecraft laboratories to provide noteworthy improvements to Space Systems Engineering Curriculum. The laboratories are: FLTSATCOM Laboratory, Spacecraft Attitude Dynamics and Control Laboratory, Smart Structures Laboratory, and Spacecraft Design Center.

SUMMARY: During 2001, several major achievements have been made in the development of these laboratories and their usage for the courses and thesis work by the students. The students in a course have used FLTSATCOM Laboratory by sending commands to the satellite for momentum wheel spin-up and firing of thrusters, and analyzing the telemetry data. Students in spacecraft attitude control course have used three-axis-attitude control simulator. Aerospace Conceptual Design Center (CDC) software has been implemented at the Spacecraft Design Center. Under spacecraft design course, the students designed an EHF (Extremely High Frequency) communications satellite. Applications of micro-electromechanical system (MEMS) for the components of nanosatellites such as thrusters, sensors and rate gyros were evaluated. Nanosatellite formation designs were also analyzed.

PUBLICATIONS:

Agrawal, B. and Okano, S., "Microelectromechanical Systems for Space Applications," *Proceedings of the 11th International Workshop on Physics of Semiconductor Devices*, New Delhi, India, 11-15 December 2001.

THESES DIRECTED:

Palermo, W., "Angular Rate Estimation for Multi-Body Spacecraft Attitude Control," Masters Thesis, Naval Postgraduate School, June 2001.

Abreu, M., "Conceptual Design Tools for the NPS Spacecraft Design Center," Masters Thesis, Naval Postgraduate School, June 2001.

Tomlin, S., "Remote Nanosatellite Formation Design with Orbit Perturbation Corrections and Attitude Control/Propulsion Subsystem Correlation," Masters Thesis, Naval Postgraduate School, June 2001.

Okano, E., "Microelectromechanical Systems for Small Satellite Applications," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Spacecraft Design, Spacecraft Attitude Control, Space Manipulator

BIFOCAL RELAY MIRROR TECHNOLOGY DEVELOPMENT

Brij N. Agrawal, Professor
Department of Aeronautics and Astronautics
Sponsor: National Reconnaissance Office

OBJECTIVE: This is NRO Director's Innovative Initiative project. The objective is to evaluate different paths in the development of fine acquisition, tracking and pointing (ATP) and beam control optics technologies for the Bifocal Relay Mirror spacecraft, do preliminary development work, and design a test bed for the development of these technologies.

SUMMARY: A team from NPS, AFRL, and Boeing performed the work on the project. Under this effort, nine tasks were performed: state-of-art technologies in ATP and beam control of optics; analytical model of the spacecraft with two gimbaled telescopes; novel electro-optical systems for beam control that are more suited for space-borne platform; target tracking systems for both cooperative and uncooperative targets; options for integrated optics and spacecraft control system design; simulations of control options; experiments to validate the acquisition, tracking and pointing control of a laser beam using steering mirrors integrated into NPS Three-Axis-Spacecraft Simulator; design of test bed to demonstrate end-to-end bifocal relay mirror spacecraft beam control, acquisition, tracking, and pointing performance; and future development efforts. The project has provided a road map for the development of this challenging technology.

PUBLICATIONS:

Agrawal, B. and Senenko, C., "Attitude Dynamics and Control of Bifocal Relay Mirror Spacecraft," AAS 01-418, AAS/AIAA Astrodynamics Specialist Conference, Quebec City, Canada, 30 July–2 August 2001.

THESES DIRECTED:

Chernesky, V., "Development and Control of a Three-Axis-Satellite Simulator for the Bifocal Relay Mirror Spacecraft," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Relay Mirror Spacecraft, Acquisition, Tracking, Pointing

METHOD OF SLEWING THE SPACECRAFT TO MINIMIZE SETTLING TIME

Brij N. Agrawal, Professor
Department of Aeronautics and Astronautics
Sponsor: Secretary of the Air Force

OBJECTIVE: The spacecraft have low frequency solar array flexible modes, which are excited during the slew maneuver. These flexible modes limit the control bandwidth and degrade the pointing error at the end of slew maneuver. The objective of this project is to develop methods to shape the torque profiles of CMGs for the slew maneuver such that at the end of slew, the vibrations are eliminated or minimized and the attitude errors are within the limits.

SUMMARY: The analytical model of NPS Flexible Spacecraft Simulator was used to evaluate different torque profiles. The torque profiles analyzed were Bang-Bang, Versine, Smoothed Bang-Bang, and Input Shaped. Using feed-forward of the torque profile reduces significantly the vibrations at the end of the slew maneuver, but it requires the inertia to be identified very accurately. A small value of the smoothing parameter is effective enough to greatly improve the performance of the Bang-Bang profile. For tight tolerance on attitude control, input shaping is most effective in meeting settling time performance.

PUBLICATIONS:

Song, G. and Agrawal, B., "Vibration Suppression of Flexible Spacecraft During Attitude Control," *Acta Astronautic*, Vol. 49, No. 2, pp. 73-83, 2001.

DoD KEY TECHNOLOGY AREASS: Space Vehicles, Sensors, Computing and Software

KEYWORD: Spacecraft Slewing

SWARM-FORMATION SATELLITE SYSTEM DESIGN

Brij N. Agrawal, Professor
Department of Aeronautics and Astronautics
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this project is to participate with the University Team, MIT, Stanford, and CALTECH on the design of Swam-Formation Satellite System. The emphasis by the NPS team will be on the mission and payload definition. The application of spacecraft design tools at the NPS spacecraft design center for use by distributed collaborative design team will be also evaluated.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Spacecraft Design, Automated Design, Distributed Design

VIBRATION SUPPRESSION AND ISOLATION IN THE IMAGING SPACECRAFT

Brij N. Agrawal, Professor
Department of Aeronautics and Astronautics
Sponsor: Secretary of the Air Force

OBJECTIVE: For an imaging satellite, vibration isolation of the imaging sensor is a critical requirement to meet its performance. For future imaging satellites with higher performance requirements, vibration isolation becomes even more critical. The objective of this project is to assess vibration suppression and isolation technologies.

SUMMARY: Under this effort, both passive and active damping techniques and different vibration isolation control techniques were evaluated. The passive damping techniques considered were viscoelastic materials, viscous fluids, eddy current damper, smart materials, and impact damper. For active control, both piezoelectric and voice coil actuators were considered. Vibration isolation techniques on previous imaging satellites and satellite under development were analyzed. In general, active damping is used for lower frequencies and passive damping for higher frequencies. Most spacecraft require a hybrid system, passive and active, to suppress the entire range of disturbance frequencies.

PUBLICATIONS:

Song, G., Schmidt, S. and Agrawal, B., "Experimental Robustness Study of Positive Position Feedback Control for Active Vibration Suppression," *Journal of Guidance, Control, and Dynamics*, Vol. 25, No. 1, January-February 2002.

PRESENTATIONS:

Chen, H., Agrawal, B. and Longman, R., "Approaches to Matched Basis Function Repetitive Control," AAS-01-369, AAS/AIAA Astrodynamics Specialist Conference, Quebec City, Canada, 30 July–2 August 2001.

Chen, H., Agrawal, B., Longman, R., Phan, M. and Edwards, S., "Rejection of Multiple Unrelated Periodic Disturbances Using MELMS with Disturbance Identification," AAS/AIAA Space Flight Mechanics Meeting, Santa Barbara, CA, 11-15 February 2001.

THESES DIRECTED:

Tarranti, C., "A Computationally Efficient Algorithm for Disturbance Cancellation to Meet the Requirements for Optical Payloads in Satellites," Ph.D. Dissertation, Naval Postgraduate School, September 2001.

Barney, T., "Adaptive Multi-Layer Controller Design and Its Application to Active Vibration Suppression on a Space Truss," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors, Computing and Software

KEYWORDS: Vibration Suppression

EFFECTS OF ROCKET MOTOR FILM-COOLED OPERATION ON EXHAUST PLUME SOOT PROPERTIES

Christopher M. Brophy, Research Assistant Professor
David W. Netzer, Distinguished Professor
Jose O. Sinibaldi, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Air Force Phillips Laboratory

OBJECTIVE: To obtain the optical properties, physical size, and mass loading of soot present in a liquid fueled Kerosene/Oxygen rocket engine and to evaluate the effects of using a film-cooled combustor's wall.

SUMMARY: The soot mass loading and associated optical properties in the exhaust of a film-cooled liquid rocket engine burning gaseous oxygen with hydrocarbon fuels were measured. The exhaust plume without film cooling was characterized over an oxygen-to-fuel (O/F) range of 0.4 to 1.5 to find soot properties expected in the fuel-rich film region. The derived baseline soot production curves for JP-8 and JP-8+100 were similar to kerosene. Soot levels derived for JP-10 were much higher than JP-8 and the predicted values over the same O/F range. Operating the engine with a core O/F of 1.5, film cooling mass-flow percentages were varied over a range of 6 to 21% of total reactants. Film layer thickness and soot mass loading both increased as percent film cooling increased. The rocket engine was operated with and without film cooling during the same run to obtain properties for the plume core and plume core with film cooling under nearly identical engine operating conditions. A vortex ring segment was used to tangentially inject the film layer. A multi-wavelength, fiber optic transmission technique, using the transmission ratio of five wavelengths (from the visible to the near IR) through the exhaust plume, was used to determine the amount of soot present.

PUBLICATIONS:

Searles, D.S., Brophy, C.M., Sinibaldi, J.O., Venner, M.J. and Johnson, C.W., "Soot Production Characteristics for JP-8, JP-8+100 and JP-10," 27th JANNAF EPTS, Brooks Air Force Base, San Antonio, TX, November 2001.

THESIS DIRECTED:

Searles, D.S., "Optical Characterization of Soot Properties in a Film-Cooled Kerosene/Oxygen Exhaust Plume," Masters Thesis, Naval Postgraduate School, December 2001.

DoD TECHNOLOGY AREA: Other (Missile Signatures)

KEYWORDS: Missile, Propulsion, Signature, IR, Soot

DEVELOPMENT OF A FIBER OPTIC TOMOGRAPHIC IMAGING DIAGNOSTIC TO MAP COMBUSTION SPECIES WITHIN ROCKET EXHAUST PLUMES

Christopher M. Brophy, Research Assistant Professor
David W. Netzer, Distinguished Professor
Jose O. Sinibaldi, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsors: Ballistic Missile Defense Organization and U.S. Air Force Research Laboratory

OBJECTIVE: To develop an optical diagnostic that can map in three-dimensions the combustion species' concentrations within a rocket exhaust plume. Furthermore, remote location of expensive infrared spectrometers is desired in order to protect them from the harsh environment created during rocket motor operation.

SUMMARY: Interest in accurate detection and targeting of aggressor missiles has received considerable interest with the national priority of developing a missile defense system. Understanding the thermal signatures of the exhaust plumes of such missiles is key to accomplishing that mission. Before signature models can be precisely developed for specific rockets, the radiation of the molecular or combustion species within those plumes must be accurately predicted. A combination translation / rotation scanning diagnostic technique has been developed to map the combustion species of a rocket plume and characterize its radiation properties. Using new infrared spectrometer and fiber optic cable technology to transmit the signal spectrum of interest, the custom designed mechanism can sweep through two dimensions of a steady-state rocket exhaust. A glow bar, or blackbody simulator, is shuttered on the opposite side of the plume, allowing the spectrometer to measure both the emission and absorption spectra. This thesis demonstrated the first time use of fiber optic cable to transmit infrared emission / absorption (E/A) spectra from a rocket plume to an infrared detector. This new fiber optic configuration allows for rapid translation and rotation around the rocket plume, establishing the capability for rapid spatial characterization of the combustion species present. Experimental results may then be compared to DoD rocket plume model predictions to highlight areas for improvement.

THESIS DIRECTED:

Kutrieb, J.M., "Rocket Plume Tomography of Combustion Species," Masters Thesis, Naval Postgraduate School, December 2001.

DoD TECHNOLOGY AREA: Other (Missile Signatures)

KEYWORDS: Rocket Plume Exhaust, Spectral Imaging, Emission/Absorption, Combustion Species, Signature

DEVELOPMENT AND CHARACTERIZATION OF A LIQUID HYDROCARBON FUELED PULSE DETONATION ROCKET ENGINE

Christopher M. Brophy, Research Assistant Professor
David W. Netzer, Distinguished Professor
Jose O. Sinibaldi, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: To develop and measure the performance of a liquid hydrocarbon fueled pulse detonation engine (PDRE) at varying operating conditions. The secondary objective was to characterize the propulsive efficiency of the PDRE using different fuels at partial fill conditions.

SUMMARY: A liquid hydrocarbon-fueled PDRE was built and successfully tested at the Naval Postgraduate School's Rocket Propulsion and Combustion Laboratory. The first time use of a new electro-hydraulic liquid fuel injector was demonstrated to produce consistent atomization properties while allowing for varying fuel injection durations at frequencies up to 50Hz. Planar laser-induced fluorescence and high-

speed imaging were used to characterize the injection flow paths of this injector. Using gaseous ethylene as a baseline for comparison, the PDRE was operated at various equivalence ratios and frequencies up to 40 Hz. Operation in partial fill scenarios was successfully conducted and found to deliver a decreased impulse linearly related to the percentage fill. A series of tests was conducted using liquid JP-10 and RP-1 fuels over varying oxidizer-to-fuel ratios. The higher pressures, wave speeds, and resulting impulse measurements revealed the benefits of using high energy density hydrocarbon fuels. The difficulty in detonating these fuels was demonstrated and overcome using a variety of different geometries and hardware configurations.

PUBLICATIONS:

Brophy, C.M., Damphousse, P.E. and Sinibaldi, J.O., "Initiator Performance for Liquid-Fueled Pulse Detonation Engines," AIAA2002-0472, 40th AIAA Aerospace Sciences Meeting, Reno, NV, January 2002.

THESIS DIRECTED:

Damphousse, P.E., "Characterization and Performance of a Liquid Hydrocarbon-Fueled Pulse Detonation Rocket Engine," Masters Thesis, Naval Postgraduate School, December 2001.

DoD TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Rocket Engine, Hydrocarbon Fuels, Space Propulsion

TECHNOLOGY INVESTIGATION FOR PULSE DETONATION ENGINES

Christopher M. Brophy, Research Assistant Professor
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Jose O. Sinibaldi, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: General Electric Aircraft Engines

OBJECTIVE: To investigate Pulse Detonation Engine's (PDE) auxiliary systems by determining minimum and optimum parameters for successful PDE operation. The secondary objective was to fully characterize those systems and their effects on overall PDE performance.

SUMMARY: Air-blast BETE atomizers were used to determine the maximum Sautter Mean Diameter (SMD) for JP8 – air spray mixtures through which a detonation wave can propagate successfully. Successful PDE operation was observed at 7Hz for JP8 sprays with SMD values less than 3.0 μm and 70% of the fuel mass in gaseous state. Larger SMD values and less than 70% fuel in gaseous state yielded unsuccessful detonation propagation. Detonation initiation was carried out via a pre-detonator where the BETE atomizers were used with JP8-Oxygen and ignition energy studies indicate that a minimum of 30mJ are needed to initiate a JP8 – Oxygen spray with SMD values between 10 and 13 μm and 0% of the fuel in the gaseous state. But more interestingly, for reliable detonation initiation, a minimum of 100mJ ignition energy levels is required. Shock focusing studies directed towards shock-induced detonation initiation were carried out with minimum improved performance, furthermore focusing of shock waves with an initial (and impractical) Mach number greater than 2.5 would be required to reliably initiate a detonation wave. In order to pursue the development of a JP8 – Air detonation initiator, a new fuel injector is required capable of producing JP8 sprays with SMD values less than 6 μm, in a cyclic operating mode at a rate of up to 100 Hz. After an extensive industry research and review, these injector requirements pointed toward a custom design made possible by Sturmann Industries. Four injectors and their respective electronic control modules were ordered and preliminary characterization has started. Promising results indicate JP8 sprays with SMD values between 7 and 10 μm can be generated at up to 100Hz operation.

PUBLICATIONS:

Brophy, C.M., Sinibaldi, J.O. and Netzer, D.W., "Effects on Fuel Distribution on Pulse Detonation Engine Operation and Performance," 15th International Symposium on Air Breathing Engines, Bangalore, India, September 2001.

Brophy, C.M., Sinibaldi, J.O. and Sexton, N., "Fuel/Air Initiator Development for Pulse Detonation Engines," *Proceedings of the 18th International Colloquium on the Dynamic of Explosions and Reactive Systems*, Seattle, WA, 29 July–3 August 2001.

THESIS DIRECTED:

Sexton, N.G., "Detonability of Hydrocarbon/Air Mixtures Using Combustion Enhancing Geometries for Pulse Detonation Engines," Masters Thesis, Naval Postgraduate School, June 2001.

DoD TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Engine, Fuel Injectors, Ignition Systems

FUNDAMENTAL STUDIES OF LIQUID-FUELED PULSED DETONATION ENGINES

Jose O. Sinibaldi, Research Assistant Professor
David W. Netzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To understand fundamental properties of initiation and propagation of liquid-fueled detonations in order to develop future pulse detonation engine systems.

SUMMARY: Design and construction of a valveless Pulsed Detonation Engine (PDE) was completed and successful operation of up to 10 Hz were attained using liquid-fuels, and up to 40Hz with gaseous hydrocarbon fuels. Ignition energy effects on deflagration to detonation transitions (DDT) showed a minimum spark with 20mJ of energy is required to initiate a propane-air or ethylene-air DDT process, but optimum DDT was obtained with a 100mJ spark. Detonation diffraction studies required to set up the following simultaneous optical diagnostics: a) high-speed digital Schlieren/Shadowgraph system capable of 17 images at a rate of up to 150 kHz with a maximum resolution of 512x512 pixels; b) a high-speed CH* chemiluminescence imaging system with similar performance to the Schlieren system. These diagnostics were applied to detonation waves diffraction from a 2" diameter tube into a 5" diameter tube, respectably the pre-detonator and the main combustor tube of a valveless PDE. Diffraction studies indicate that a minimum of 7 detonation wave cell widths are needed in the pre-detonator in order for the detonation wave to successfully diffract into the PDE main combustor. These results are an indication of the detonable mixtures' kinetic rates and further investigations are deemed necessary to obtain quantitative results.

PUBLICATIONS:

Brophy, C.M., Sinibaldi, J.O. and Netzer, D.W., "Effects on Fuel Distribution on Pulse Detonation Engine Operation and Performance," 15th International Symposium on Air Breathing Engines, Bangalore, India, September 2001.

Brophy, C.M., Sinibaldi, J.O. and Sexton, N., "Fuel/Air Initiator Development for Pulse Detonation Engines," *Proceedings of the 18th International Colloquium on the Dynamic of Explosions and Reactive Systems*, Seattle, WA, 29 July–3 August 2001.

DoD TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Engine, Fuel Injectors, Ignition Systems

CONTROL COMPRESSIBLE DYNAMIC STALL USING A VARIABLE DROOP LEADING EDGE VR-12 AIRFOIL

M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army (NASA) Aero Flight Dynamics Directorate

OBJECTIVE: To investigate compressible dynamic stall control using a Variable Droop Leading Edge (VDLE) Concept.

SUMMARY: In an attempt to meet the US Army TDA, a new way of controlling dynamic stall that can exploit the progress in smart materials, the concept of drooping an airfoil leading edge steadily as it pitches up to high angles of attack is being tested in this project. The technique holds special promise for compressible dynamic stall control since it is a leading edge type of stall. A 6-inch chord VR-12 (Boeing Vertol) airfoil has been designed, and fabricated with 20 unsteady pressure transducers installed on it. The design incorporates features to bring out all the power and signal leads through the ¼-chord point, the only stationary point in the system. The leading 25% of the airfoil can droop to as large as –25 degree relative to the main element dynamically and it can be preset to any desired value as well. A comprehensive data acquisition and processing software has been developed for online, real time display of the large sample set of unsteady data that is collected during the tunnel runs. Both instantaneous and ensemble averaged data along with integrated quantities can be displayed in real time. The pressure transducers were individually calibrated using suction cups to enhance measurement accuracy. Testing is now ongoing. Already, preliminary data has been collected for various flow conditions and integrated force and moment loops calculated. This early data set has shown that the concept and the studies are worth further exploration and hence, detailed testing is planned for CY 2002. The project is now also a specific task in the U.S. Army (AFDD) - German DLR MOU program.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Variable Geometry Airfoils, Dynamic Stall, Rotor Blade Flow Control

EXPERIMENTAL STUDIES OF COMPRESSIBLE DYNAMIC STALL

M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army (NASA) Aero Flight Dynamics Directorate

OBJECTIVE: To investigate compressible dynamic stall control using the oscillatory blowing technique on a trailing edge stalling oscillating NACA 0015 airfoil.

SUMMARY: This effort aims to control compressible dynamic stall using oscillatory blowing from a Boeing Company supplied actuator through a 0.02-inch slot in a 6-inch chord NACA 0015 airfoil. This work is also being carried out as a specific task in the U.S. Army (AFDD)/ Israel MOU. Preliminary trials at controlling stall were found to be partly successful. Considerable difficulties were experienced by the strong airfoil peak suction pressure, which caused the actuator diaphragm to be held at one end of its stroke, largely eliminating its pumping functionality. Enclosing the actuator in a controlled vacuum chamber was expected to mitigate these problems as was confirmed by further tests. But, the primary limitation was the fact that as the flow Mach number was increased, the blowing capabilities required increased significantly and a need for multiple actuators became apparent. Also, the frequency requirements became high for the actuators available. A new manifold system has been designed which can house two separate blowers, with the air path through the outlet ducting optimized for enhanced performance to be derived from a synchronous operation of the actuators. Further work in this regard is contingent upon AFDD providing the support to fabricate this design.

PUBLICATIONS:

Chandarsekhara, M.S., "An Exploratory Investigation of Pulsatile Blowing to Control Compressible Dynamic Stall over an Oscillating NACA 00125 Airfoil," Final Report submitted to the U.S. Army Research Office, April 2001 with copy to AFDD.

PRESENTATIONS:

Tung, C., Dr., "Experimental Studies of Compressible Dynamic Stall," US Army /Israel MOU meeting, Israel, March 2001.

Chandrasekhara, M.S. and Tung, C., Dr., "Experimental Studies of Compressible Dynamic Stall," AFDD at NASA ARC, October 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Flow Control, Helicopter Blade Stall, Oscillatory Blowing

FLUID MECHANICS OF COMPRESSIBLE DYNAMIC STALL CONTROL USING DYNAMICALLY DEFORMING AIRFOILS

M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Research Office

OBJECTIVE: To develop flow control schemes through management of the unsteady vorticity field by dynamically deforming an airfoil for prevention of flow separation.

SUMMARY: This year the project was focused on further testing of the 6-inch chord NACA 0012 airfoil instrumented with 148 surface hot-film gages to identify the surface shear stress behavior in this flow at conditions representative of a helicopter retreating blade. Detailed analysis of the data was carried out using MATLAB tools and also, some other tools developed in-house. The most spectacular result was the identification of the common precursor to compressible dynamic stall as the rapid rise in surface shear stress for all different dynamic stall onset mechanisms discovered in our earlier investigations. This provides us a new tool with which to attempt to closed-loop control of compressible dynamic stall. Other results with significant implications were the documentation of the shock imprint in the surface flow signature, the dramatic movement of the transition onset point on the airfoil upstroke and the flow relaminarization during its down stroke as it reattaches from the deep stall state, both of which affect all computational studies conducted so far. It is now clear that success in computational fluid dynamic modeling of the flow requires incorporation of the new physics uncovered from these studies. The project has now concluded and a final report to ARO has been submitted.

PUBLICATIONS:

Chandarsekhara, M.S., "Fluid Mechanics of Compressible Dynamic Stall Control Using Dynamically Deforming Airfoils," Final Report submitted to the U.S. Army Research Office, November 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Flow Control, Helicopter Blade Stall, Smart Materials, Deforming Airfoils

SUPPORT OF FSU/FAMU EXPERIMENTAL STUDIES OF COMPRESSIBLE DYNAMIC STALL

M.S. Chandrasekhara, Research Professor
Department of Aeronautics and Astronautics
Sponsor: Florida A&M University

OBJECTIVE: To investigate compressible dynamic stall control using supersonic micro-jets.

SUMMARY: A novel flow control approach that uses blowing a large number of supersonic micro-jets into the flow has demonstrated promise in controlling jet noise and other practical flow issues. Florida State university researchers are now attempting to use the same technique to control compressible dynamic stall. This proof of concept study needs a facility specifically designed for the problem and the NASA/FML Compressible Dynamic Stall Facility is being used for the effort. Assistance to meet the exacting requirements of model design, supporting methods, factors of safety needed to be satisfied at NASA prior to receiving approval for testing a new model and the necessary training to use the facility, the measurement technique of point diffraction interferometry and the custom built electronic phase interlocking system is being provided for the project. At the time of writing, the model design, fabrication with about 540 micro-jets drilled on the airfoil upper surface from the leading edge to x/c = 0.25 is complete. Component integration with the air blowing system is ongoing. It is proposed to use the steady supply of shop air for this effort to blow at about 100 psia pressure to explore the flow control capabilities of this approach.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Micro-jet Blowing, Dynamic Stall, Rotor Blade Flow Control

AIR-GROUND RAPID RETARGETING SYSTEM

Russell W. Duren, Associate Professor
Issac Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command

OBJECTIVE: The objective of this proposal is to continue to investigate design requirements and technical problems related to the development of a closed system which will accept, transmit and verify weapon targeting information using existing/planned C4I system to provide off-board targeting information to combat aircraft enroute to combat areas.

SUMMARY: Research concentrated on investigating design requirements and technical problems related to the development of a closed system which will generate and transmit targeting information using the existing/planned C4I system to provide off-board retargeting information to a generic GPS-guided standoff weapon. A conceptual system was developed that used generic sensor platforms and a ground-based targeting processor to provide targeting data to a generic standoff weapon via a Link-16 data link. A simulation model was developed in order to investigate the response of the proposed system to various combinations of identified error sources. The preliminary design of a simulation model was completed. Initial coding of the simulation model was performed using Statemate MAGNUM from I-Logix, Inc. Final coding was completed using MATLAB Simulink. The simulation model was developed in a modular fashion to allow future expansion. Initially generic modules are being used for the target behavior, the sensors, the targeting processor, the data link, the weapon flight characteristics, and the weapon effects on the target. Due to the modular nature of the simulation model each of these modules will be capable of being replaced by more sophisticated or less generic modules in the future. Results of simulation with the generic models were used to predict the overall contributories of system variables to weapon accuracy.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Air Vehicles, Path Real-Time Information in the Cockpit, Targeting, Time Critical Strike

ANALYSIS OF TRACKING CHARACTERISTICS AND IDENTIFICATION CONTRIBUTIONS OF DIVERSE SYSTEMS AND DATA SOURCES FOR MULTIPLE SOURCE INTEGRATION/DATA FUSION

Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center - Aircraft Division

OBJECTIVE: The objective of this proposal is to provide a single fused track for each contact of interest in the battlespace using the multiple source integration/data fusion (MSI/DF) concept. This research supports MSI/DF initiatives being developed by PMAS-231, Northrup-Gruman Corporation, and the Office of Naval Research for the E-2C Hawkeye aircraft. A fused track will be representative of all available sources of data contributing to that track. The combat identification (CID) process will tie together all identifying attributes of these tracks to enable a CID decision based on the track identification parameters.

SUMMARY: In the Command and Control mission, new technologies such as 'sensor fusion' are designed to help reduce operator workload and increase situational awareness. This research explored the tracking characteristics of diverse sensors and sources of data and their contributions to a fused tactical picture. The fundamental building blocks of any sensor fusion algorithm are the tracking algorithms associated with each of the sensors on the sensor platform. In support of this study, the MATLAB program 'fusim' was written to provide acquisition managers a tool for evaluating tracking and sensor fusion algorithms. The fusim program gives the user flexibility in selecting: sensor platforms, up to four sensors associated with that platform, the target types, the problem orientation, and the tracking algorithms to be used with the sensors. The fusim program was used to compare tracking algorithms in a multiple sensor/multiple target environment. Specifically, the Probabilistic Data Association Filter, the Interacting Multiple Models Filter, the Kalman Filter and the Constant Gain Kalman Filter were evaluated against multiple maneuvering, non-maneuvering, and fixed targets. It is recommended that this study be continued to evaluate advanced tracking and data association techniques, to expand the program to allow attribute tracking and identification, and to study the Human-Machine Interface aspects of sensor fusion.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Sensor Fusion, Data Fusion, Multiple Source Integration

UHF ELECTRICALLY SCANNED ARRAY (UESA) STUDY

Russell W. Duren, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command

OBJECTIVE: The objective of this proposal is to investigate computer architecture and processing issuer related to the development and testing of a UHF electrically scanned array (UESA).

SUMMARY: Two papers were written related to the UESA system. On paper summarizes computer architectures and benchmarks for the Space-Time Adaptive Processing algorithms required for processing the UESA data. The second paper compares the tactical performance of the proposed UESA antenna to the ADS-18 linear electronically scanned array antenna currently being considered as part of the E-2C Radar Modernization Program.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communication

KEYWORDS: Airborne Early Warning, Avionics, Computer Architecture, Cooperative Engagement Capability, Electrically Scanned Array

CASCADE VORTEX-SHEDDING STUDY

G. V. Hobson, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: National Aeronautics and Space Administration - Glenn Research Center

OBJECTIVE: Vortex shedding from the trailing edge of an upstream blade row will increase the frequency of excitation on a subsequent blade row in a multistage compressor. This increased frequency, over the blade passing frequency, could lead to destructive high cycle fatigue problems.

Current unsteady computational fluid dynamics codes have the ability to predict vortex shedding, however little experimental data is available particularly in modern designed compressor blades which have relatively blunt trailing edges. Since the Turbopropulsion Laboratory of the Naval Postgraduate School current has a set of second-generation Controlled-Diffusion blades installed in the Low Speed Cascade Wind Tunnel, it is ideally suited to perform a vortex shedding study on these blades.

SUMMARY: Three inlet flow angles (31, 33 and 35 degrees) were investigated at three Reynolds numbers (280,000, 380,000 and 640,000). Laser-Doppler-velocimetry (LDV) and hotwire surveys were performed across the wake to determine the unsteady flow parameters associated with the vortex shedding. Spectral analyses of the hotwire measurements were performed to determine the vortex shedding frequency and extend of the vortices.

THESES DIRECTED:

Brown, P., "Investigation of Vortex Shedding in a Cascade of Controlled-Diffusion Compressor Blades," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Turbine, Laser, Velocimetry, Vortex Shedding

TURBINE TIP-LEAKAGE FLOWS

G. V. Hobson, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center - Aircraft Division

OBJECTIVE: This project entails non-intrusive, laser-Doppler-velocimetry (LDV) measurements in the endwall region of a turbine. A paper was presented at the Aerospace Sciences Conference in Reno, NV in January 2001. The specific turbine test article is the turbine of the High Pressure Fuel TurboPump (HPFTP) of the Space Shuttle Main Engine (SSME) and the particular hardware was designed and manufactured by Pratt & Whitney for NASA.

SUMMARY: The turbine rig was recommissioned after the heat exchanger between the compressed air supply and the turbine was replaced. A paper was presented on the measurements and computations performed on the first stage of the turbine. During the recommissioning (performed by students in an Advanced Aerodynamics Measurements course) the data acquisition (DAQ) system was upgraded to the latest version of LabView. A HP VEE DAQ system was also developed as part of the upgrade.

PUBLICATIONS:

Hobson, G.V., Anderson, S.C., McKee, J. and Southward, J., "Experimental and Numerical Investigation of the Tip Leakage Flow in the Single Stage Turbine of the Space Shuttle Turbopump," AIAA 2001-0831, presentation at the 39th Aerospace Sciences Conference, Reno, NV, January 2001.

THESES DIRECTED:

Anderson, C.S., "Analysis of the Tip Leakage Flow Field in an Axial Turbine," Masters Thesis, Naval Postgraduate School, June 1999.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Turbine, Laser, Velocimetry, Tip-leakage Flows

CONTINUED DEVELOPMENT OF THE AFFORDABLE GUIDED AIRDROP SYSTEM

Richard M. Howard, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: The objective of this proposal is to continue efforts in the development of a low-cost guidance, navigation, and control system for airdrop leading to the demonstration of autonomous guidance of a flat-circular parachute; to support this effort with simulation, hardware development, model development, instrumentation development, and assistance with data analysis, test planning, and system demonstration.

SUMMARY: This part of the project had two components: 1) the development of an aerodynamic model of a controlled flat-circular parachute, and 2) the development of an instrumentation package for personnel parachute application. The previous development of round parachute aerodynamic models was reviewed, and a five-degree-of-freedom model was proposed. An instrumentation package consisting of a datalogger, three low cost rate sensors, three linear accelerometers, a pressure sensor and a GPS card was designed based on similar work at NASA Dryden Flight Research Center.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Airdrop, Parachute, Autonomous Guidance, Modeling

PERSONNEL PARACHUTE INSTRUMENTATION SYSTEM

Richard M. Howard, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground and Naval Postgraduate School

OBJECTIVE: To develop, test, and demonstrate an onboard sensor and data collection package for personnel parachute systems, to determine and record descent rate, oscillation angles, impact velocity, and shock-opening loads. The work is part of a continuing project.

SUMMARY: Based upon former work of NASA Dryden personnel, a prototype instrumentation package using low-cost sensors capable of measuring and recording three angular rates, three linear accelerations, barometric pressure, and GPS position and velocity data was constructed at NPS and tested at Yuma Proving Ground. Tests were performed on "door bundle" and mannequin test articles dropped under parachutes. The instrumentation package was well-suited to the application (being designed to fit on a jumper's chest) with accessible flush switches. Commercial development will follow by a vendor chosen by the sponsor. The project continues, to aid in its commercial development and to complete the inclusion of additional memory storage at various logging rates. Other rate sensors may be tried as well.

OTHER: A prototype instrumentation package was designed, constructed, tested, and delivered.

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

KEYWORDS: Instrumentation, Parachute, Sensors, Testing

INTEGRATION AND FLIGHT TEST OF UCLA'S NAVIGATION COMPUTER ON NAVAL POSTGRADUATE SCHOOL'S UAV *FROG*

Issac I. Kaminer, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: The objective of this proposal is to integrate and flight test the navigation computer developed by UCLA and NASA Goddard on NPS's UAV *FROG*. Specifically, formation flights that include NPS's *FROG* and UCLA's UAV *MULE* will be conducted at Camp Roberts Flight Test Range starting at the end of May 2000 and continuing through September 2001.

SUMMARY: The work was completed in December of 2001. Additional flight testing is planned for 2002.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Air Vehicles, Unmanned Air Vehicles, Flight Test

AEROTHERMOELASTIC STUDIES OF HYPERSONIC FINS

Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center

OBJECTIVE: Aerothermoelastic analysis of a hypersonic fin will be performed. Thermal effects on the structural dynamic response and flutter of the fin will be performed using the aeroelastic analysis tools and for selected temperature distribution. Piston theory and ZONA50 supersonic theory will be used in fin and effects of aspect ratio and in-plane loads will be reported.

SUMMARY: An aerothermoelastic analysis of missile fins at high speeds is performed. Following conclusions may be drawn from the results reported: (1) the thermo elastic analysis shows certain thermal instabilities at elevated temperatures; (2) both the vibrational response and the flutter response analyses are presented within the stable thermal loads. The natural frequencies, in general, decrease as the temperature is increased. The flutter analysis reveals that the fin is flutter free for the speeds considered; (3) The panel flutter analysis show that the panel geometries considered are flutter free if high strength - high stiffness material (Haynes S-230, E = 25E6 psi) is used instead of 2024 Aluminum with E = 10.3E6 psi. Any other geometric variations need analysis prior to construction; (4) Flutter boundaries are obtained for the missile fin under no thermal loading. These flutter boundaries are presented in the form of non-dimensional flutter parameter as a function of Mach number. The flutter boundaries are developed for various altitudes and given as a composite flutter boumdary plot. Such flutter boundary design data provides useful information for assessing the flutter margins and structural safety.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Materials, Processes, and Structures

KEYWORDS: Missiles, Aeroelasticity, Dynamics, Structures, NASTRAN, Hypersonic Weapons

FINITE ELEMENT MULTI-DISCIPLINARY ANALYSIS OF FLIGHT VEHICLES

Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: Develop new capabilities for a multidisciplinary finite element analysis tool for flight vehicles. Demonstrate by means of validation and verification the capabilities of the simulation software as applied to practical problems.

SUMMARY: NPS developed efficient solution methods and validation utilizing the finite-element method for simulating the dynamic maneuvering of advanced flight vehicles. A multi-disciplinary approach was taken to involve interactions including those between aircraft structures, computational fluid dynamics, controls and design optimization. Several application problems involving large number of degrees of freedom were verified using the software for efficiency and accuracy.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles, Materials, Processes, and Structures

KEYWORDS: Finite Element Analysis, Multi-Disciplinary Analysis, Computational Fluid Dynamics, Aeroelastic Analysis, Composites and Buckling

IMPROVED TARGET ACCURACY AND SENSOR AIMING FOR RAH-66 WEAPONS SYSTEM

Ramesh Kolar, Research Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: The objective of this proposal is to use the MSC/NASTRAN Structural Dynamic Model of the RAH-66 helicopter to determine biases between sensor loss and weapon pointing to the target for specified conditions as a function of the flight envelope. Weapons of interest are three–barrel, nose mounted 20-mm turreted Gatling gun. Sensors include FCR, TV, and FLIR. Actual measured gun loads will be used for the analysis.

SUMMARY: Modeling of the structural dynamic behavior of the RAH-66 Comanche vehicle under the specified gun loads was completed. This phase of the work constituted a follow up of the error budgets generated for the weapon systems for the helicopter.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Air Vehicles

KEYWORDS: Helicopter, Rotorcraft, Dynamics/Structures, NASTRAN

MODELING, SIMULATION AND VALIDATION OF RAH-66 WEAPONS SYSTEM

Ramesh Kolar, Research Assistant Professor
E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: To implement dynamic finite element model of the RAH-66 Comanche helicopter and perform simulations to study the behavior of the weapons system interaction with the helicopter structure.

SUMMARY: The latest dynamic finite element model of the RAH-66 Comanche helicopter developed by Sikorsky was implemented on a NPS computer. Simulation of the structural dynamic behavior using MSC/NASTRAN and PATRAN was performed. Results were correlated with sponsor's data. Response of the helicopter to steady applied loads was performed. Consultation was provided to the sponsor in the modeling and simulation of the gun control system. Also, studies to understand modal testing and dynamic alignment algorithms for the gun control system were performed.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Air Vehicles

KEYWORDS: Modeling and Simulation, Helicopters, Dynamics/Structures, NASTRAN, Dynamic Alignment

MULTI-ROLE ENDURANCE/STRIKE SUPPORT UNINHIBITED COMBAT AIR VEHICLES (UCAVs)

Conrad Newberry, Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: The primary objective of this proposal is to define the system integration issues for two notational UCAVs capable of performing multi-role endurance and/or strike Naval support for the littoral battlespace.

SUMMARY: Two conceptual uninhabited combat air vehicles (UCAVs) were designed to meet multi-role endurance/strike requirements: *FLIPPER* and *SEA ARROW*. The *FLIPPER* concept has a thrust-to-weight ratio of 0.77 and a wing loading of 20 psf. It is a multi-role aircraft capable of providing reconnaissance, surveillance, targeting, and data/voice relay (RSTR) to Navy and Marine Corps forces operating in the 21st century. *FLIPPER* has a payload weight of 750 lbf and a takeoff weight of 5,600 lbf. The unit flyaway cost is $5.9M and MMH/FH = 5.3.

SEA ARROW was a semi-tailless aircraft designed for an armed reconnaissance mission. The *SEA ARROW* concept has a thrust-to-weight ratio of roughly 0.65 and a wing loading of approximately 32. *SEA ARROW* carries a weapons payload of 1,500 lbf and can takeoff in 387 feet (40 kt head wind); 785 feet with no wind. Takeoff weight is 15,000 lbf. Unit flyaway cost is $9.5M; MMH/FH = 8.8 and mission effectiveness is 0.609 (compared to unity).

DoD KEY TECHNOLOGY AREAS: Human Systems Interface

KEYWORDS: Uninhabited Combat Air Vehicles, Medium Altitude Endurance, Naval Support, Multi-Role

ASRAAM MISSILE LAUNCH LOAD ANALYSIS

Max F. Platzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center

OBJECTIVE: To contribute to the analysis of missile launch loads from F-18 aircraft

SUMMARY: Consulting services were provided to the Naval Air Warfare Center, Patuxent River, to assist in the analysis of the ASRAAM missile high G launch loads performed by the Nielsen Engineering & Research Company

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Missile Aerodynamics, Missile Launch Loads

COMPUTATIONAL STUDY OF ABRUPT WING STALL

Max F. Platzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Office of Naval Research

OBJECTIVE: The objective of the proposed investigation is the computational prediction of abrupt transonic wing stall using advanced Navier-Stokes codes.

SUMMARY: Reynolds-averaged Navier-Stokes computations were completed to predict the transonic flow over a complete f/A-18 E/F aircraft configuration and over a simplified fighter aircraft wing/LEX/body configuration. Data in the pre and post-stall regime were obtained and it was shown that a small change in the cross-sectional area distribution in the aft body has a significant effect on the onset of wing stall, thus indicating that transonic area ruling has the potential to alleviate transonic wing stall.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Transonic Aerodynamics, Wing Stall, Computational Fluid Dynamic

DEVELOPMENT OF MICRO-AIR VEHICLES

Max F. Platzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Research Laboratory

OBJECTIVE: To develop a micro-air vehicle which uses flapping-wing propulsion.

SUMMARY: A number of computational and experimental investigations of the flow over flapping wings suitable for the propulsion of micro-air vehicles were completed. The computational studies were based on two-dimensional potential flow and viscous Navier-Stokes solutions for the flow over flapping airfoils and airfoil combinations. Several wind tunnel models of varying scales and complexity were developed and tested in a low-speed flow visualization tunnel. The thrust was measured directly and compared with the numerical predictions. Measured thrust for the larger model compared well with the numerical predictions. Also, the oscillatory flow was measured with a laser-doppler velocimeter. The smaller model revealed a significant Reynolds number effect which could be explained as being due to the onset of dynamic stall vortices shed from the leading edges.

THESES DIRECTED:

Castro, B.M., "Multi-Block Parallel Navier-Stokes Simulation of Unsteady Wind Tunnel and Ground Interference Effects," Ph.D. Dissertation, September 2001.

Mahmoud, O.M.K.M., "Experimental Investigation of Low Speed Flow over Flapping Airfoils and Airfoil Combinations," Ph.D. Dissertation, September 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Micro-Air Vehicles, Low-Speed Aerodynamics, Unsteady Aerodynamics, Flapping Wings

EVALUATION OF A NEW APPROACH TO EFFICIENT TRAJECTORY OPTIMIZATION

I. Michael Ross, Associate Professor
Department of Aeronautics and Aeronautics
Fariba Fahroo, Associate Professor
Department of Applied Mathematics
Sponsor: Draper Laboratory

OBJECTIVE: The objective of this research was to evaluate the applicability of spectral methods to handle nonlinear trajectory optimization problems. Included in this evaluation is the question of the efficiency of spectral methods to handle state discontinuities such as those arising in launch vehicle trajectory optimization.

SUMMARY: The evaluation was conducted in part at Draper Labs (Ross) and at NPS (Fahroo). Services were also provided to Draper Labs in the form of advising staff (Draper) and MIT graduate students. Several trips by Professor Fahroo to Draper labs further facilitated cooperative research between Draper Labs and NPS. Significant outcomes of this cooperative research were: an independent demonstration by Richard Philips (Draper) in the use of pseudospectral methods for launch vehicle trajectory optimization, and an MIT Masters' Thesis by Jeremy Rea (advised by Ross and others) which showed the feasibility of using pseudospectral methods for model-predictive guidance in addition to its capability to handle table look-up data.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Optimal Control, Trajectory Optimization, Launch Vehicle Guidance

EVALUATION OF A PREDICTIVE METHOD FOR NEAR-OPTIMAL GUIDANCE

I. Michael Ross, Associate Professor
Department of Aeronautics and Aeronautics
Fariba Fahroo, Associate Professor
Department of Applied Mathematics
Sponsor: Draper Laboratory

OBJECTIVE: The goal of this research was to evaluate the capability of solving linear-time-varying quadratic optimal control problems without the aid of differential Riccati equations.

SUMAMRY: Linear time-varying systems with quadratic cost arise quite frequently in the design of guidance and control systems. In particular, they facilitate the notion of neighboring optimal control laws. For predictive control methods to work efficiently, it is necessary to avoid solving Riccati equations on-line. In this project a new method developed at NPS was evaluated for on-line (i.e. real-time) implementation. This method does not use Riccati methods but solves the accessory minimum problem using an indirect Legendre pseudospectral method. The evaluation process demonstrated that the new method was capable of solving such problems on line without incurring loss in accuracy employed in the approximation.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles

KEYWORDS: Guidance and Control, Symplectic Boundary Value Problems, Riccati Methods.

SABBATICAL RESEARCH AT DRAPER LABS

I. Michael Ross, Associate Professor
Department of Aeronautics and Aeronautics
Sponsor: Naval Surface Warfare Center

OBJECTIVE: This proposal is for researching the design of optimal gimbal tumbling for INS error reduction during the boost and bus phases of the Trident Missile. The task will be performed as part of the Principal Investigator's sabbatical at the Charles Stark Draper Laboratory in Cambridge, MA.

SUMMARY: Classified.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Inertial Navigation, Missile Guidance

ADVANCED FAN AND COMPRESSOR DEVELOPMENT STUDIES

Ray P. Shreeve, Professor
Garth V. Hobson, Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center - Aircraft Division

OBJECTIVE: To develop or validate tools for the design of advanced compression systems for Navy engines. Four tasks are ongoing: (i) to obtain experimental measurements and observations of CD blade stall for CFD code validation; (ii) to develop a geometry package geared to the design (by CFD analysis) of swept transonic blading, and to facilitate design optimization; (iii) to install and test an advanced transonic axial stage, and thereby establish the means to evaluate more advanced designs economically; (iv) to develop advanced measurement capability.

SUMMARY: (i) Three-component LDV measurements of the end-wall flow field of the cascade were performed in a thesis study by Caruso. Measurements were taken on four grids spanning one blade passage from center span to the end wall, one upstream of the cascade and three downstream in the wake. Hence a full 3D data set, including loss measurements obtained in the earlier thesis study by Carlson, was produced at an inlet flow angle of 40 degrees (+4 deg. Incidence). Also, a paper on the measurement of separation bubbles at three different Reynolds numbers in the cascade was published in the *AIAA Journal of Propulsion and Power*. (ii) A new Bezier-surface representation of axial transonic blading, requiring only 32 control points and two parameters, was developed in an earlier Ph.D. study by Abdelhamid. The ability to easily introduce sweep etc. was demonstrated. A current Ph.D. study aims to use the geometry package to optimize a fan rotor design. To date it has been shown that the Sanger rotor can be modified to increase pressure ratio, flow rate and efficiency, with lower blade stresses. The procedure will now be applied to other rotors. (iii) Test data from the compressor rig are being compared with code analysis. The complexity of the computational model of the Sanger stage has been increased by including an inlet grid which models the spinner and inlet ducting, and tip grids over both the rotor and stator. Preliminary calculations of the 100% and 80% near peak efficiency points have produced improved results. (iv) Application of pressure-sensitive paint to the Sanger rotor test is awaiting the construction of an aluminum and Plexiglas modular case wall. A tip-timing technique for measuring the vibrations of rotor blades using laser-light probes, was implemented successfully in the HCF/Spin Test Research program.

PUBLICATIONS:

Hobson, G.V., Hansen, D.J., Schnorenberg, D.G. and Grove, D.V., "Effect of Reynolds Number on Separation Bubbles on Controlled-Diffusion Compressor Blades in Cascade," *Journal of Propulsion and Power*, Vol. 40, No. 1, pp 154-162, January-February 2001.

THESES DIRECTED:

Caruso, T.M., "Three-Component LDV Measurements of Corner Vortices over Second-Generation Controlled-Diffusion Compressor Blades in Cascade," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Controlled-Diffusion Blading, LDV Measurements, Compressor Cascade Stall, Transonic Compressor Design, Pressure-Sensitive Paint (PSP)

HCF/SPIN TEST RESEARCH

Ray P. Shreeve, Professor
Garth V. Hobson, Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center - Aircraft Division and Naval Postgraduate School

OBJECTIVE: To develop high-cycle fatigue (HCF) spin-test techniques using an engine-scale vacuum spin-pit. Following the successful implementation of air-jet excitation (AJE), oil-jet excitation (OJE) and eddy-current excitation (ECE) techniques using two small rotors, present goals are to apply similar techniques to full-scale engine rotors, and to perform tests to evaluate blade damping techniques. The program is conducted in close association with NAWCAD, and with the participation of Hood Technology Corporation, jointly funded by the Air Force.

SUMMARY: An exploratory test program using a small titanium rotor and a program to evaluate stick dampers in a full-scale XTE 66 LPT-2 partially bladed rotor were completed. Peak-peak unsteady stress levels of 11kpsi were produced with ECE in the eleven-inch diameter titanium rotor, but tests were limited to a few minutes by heating. OJE produced over 80kpsi, but an oil recovery system needed to be developed to enable endurance testing using oil. AJE at 8, 10, 12 engine order (EO, or RPM) was used to excite the lowest resonant mode of the XTE 66 rotor, and information on damping was obtained. Attempts to excite higher order modes at 200EO with a partial array of air jets gave very low unsteady stress levels, but the reasons were well understood. Progressively higher levels of excitation were obtained with ECE when magnets were used at the blade tips as well as the trailing edges, and when silver plating was applied to the nickel blade surfaces. However in the targeted mode, excitation levels were not high enough to evaluate the effectiveness of dampers. Considerable progress was made in unsteady measurement techniques. A two laser-light probe 'time-of-arrival' blade deflection system was calibrated successfully (to strain gauge measurements) to infer unsteady stresses in all blades. It was seen then that the blade response depended on its position in the rotor, and that very consistent behavior was obtained if a start-stop test procedure and averaging was used.

The refurbished spin-pit facility at the turbopropulsion laboratory serves as the Navy research facility for high-cycle fatigue (HCF) – related spin testing. Eddy-Current excitation of an F119 fan is planned first, in association with hood technologies, Inc. Unsteady response measurement and analysis capability will be developed, and will be applied in a follow-on program, which will be a coordinated part of the national HCF initiative. The overall program will be conducted in close collaboration with NAWCAD personnel and will support the NAWCAD program in HCF.

PRESENTATIONS:

Mercadal, M., von Flotow, A. and Roesler, C., "Results of Eddy Current Excitation of Blade Vibration in a Series of Rotors," 6th National Turbine Engine High Cycle Fatigue Conference, Jacksonville, FL, 5-8 March 2001.

Shreeve, R.P., Hobson, G.V., Seivwright, D.L. and Pickering, R., "Navy HCF/Spin Test Program," 2001 Passive Damping Action Team Meeting, Pittsburg, PA, 31 July 2001.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Spin Testing, High Cycle Fatigue, HCF, Spin-Pit Facility, Gas-Turbine Blade Excitation

SATELLITE SERVICING LABORATORY

Michael G. Spencer, Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Air Force Research Laboratory and Naval Postgraduate School

OBJECTIVE: The objective of this research is to develop an autonomous servicing spacecraft simulator and test-bed. The simulator will be used for the development and validation of autonomous, neural network based control algorithms as well as various hardware elements necessary for autonomous rendezvous and docking, space manipulator control, and satellite servicing operations.

SUMMARY: The first year of effort was very successful with considerable progress made in the design and development of the servicing satellite test-bed. The servicing satellite simulator was designed as a test-bed for the autonomous rendezvous/docking systems. The simulator includes a robotic servicing vehicle and a separate target vehicle.

The servicing vehicle has a modular design so as to accommodate and test various vision and docking systems. A robotic arm will be able to integrate different end-effectors for "soft dock" and grapple tests with the target vehicle. The realtime control system will be developed and implemented using a PC based system with Lab VIEW to enable rapid integration and testing. Cold gas thrusters and a momentum wheel are to be used to translate and rotate the servicing vehicle about the workspace. A summary of the work accomplished and the current design of the vehicle follows:

- Power and computer connections were installed in the laboratory room.
- Tables, cabinets and computers have been installed to support two students design and research efforts.
- Most of the components necessary to build the servicing satellite vehicle have been procured. These items include a reaction wheel, air thrusters, air pads, air tanks, cameras, arm motors, a rate sensor, accelerometers, a PXI control computer, and a Data Acquisition computer.
- Software to support the lab that has been purchased included Lab VIEW, Matlab and a student version of AutoCad.

In addition to the support from NPS, additional reimbursable support ($50K) was obtained from the Air Force Research Laboratory. These funds directly supported the procurement of critical hardware for the satellite test-bed. Future reimbursable funding from AFRL is expected for fiscal year 02. Two Naval graduate students have signed on with the lab to do their thesis research in the development and testing of the satellite test-bed. The students are currently involved in the lab by designing and preparing the lab for the assembly and testing of the robotic servicing vehicle.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Satellite Servicing, Autonomous Control, Neural Networks, Free-Flying Satellites

RESEARCH IN DAMPER FREE ROTOR DESIGN BASED ON MAPLE NONLINEAR SIMULATION

E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: U.S. Army Research Office

OBJECTIVE: The objective of this work was to derive the full non-linear lead-lag equations of motion for a multiblade rotor. Apply this new expanded analysis in two areas with high potential for eliminating reliance on mechanical damping in helicopters. These are by introduction of structural tailoring to provide nonlinear hingeless rotor lead/lag characteristics, and by swashplate feedback for increased lead/lag stability. Initial work was to treat the dynamic system in a vacuum. This was to be followed by introducing

unsteady aerodynamics into the problem. The significance of this new research is that it has the potential to benefit all military services, since Army, Navy, Marines and the Air Force employ helicopters extensively. Lead-lag instability, when it occurs, can build up to destructive proportions in a matter of seconds.

SUMMARY: Work for the year 2001 was carried out by P.I., Prof. E. Roberts Wood of NPS, with support from Professor David Canright of the NPS Mathematics Dept., CDR Mark A. Couch, NPS Lecturer and doctoral student, Assistant Professor Robert L. King of Mississippi State University, and Dr. Ronald W. Duval, Advanced Rotorcraft Technology, Inc. of Mountain View, CA. Work was in three areas:

- Toward improved methodology for the ARO-NPS Rotor-Fuselage Nonlinear Dynamic Model and reducing computation time.
- Toward development of a full-scale OH-6A helicopter for ground and flight tests of concepts to control or eliminate ground and air resonance.
- Toward incorporating unsteady aerodynamic theory into the ARO-NPS Rotor-Fuselage Nonlinear Dynamic Model with applications to Higher Harmonic Control, tiltrotor aeromechanics, and the vortex ring state flight regime (See NPS presentation for ARO Ninth Aeroelastic Workshop at University of Michigan which has a work-in-progress report on this work).

The year 2001 marked the completion of this 3-year ARO project (ARO Project 37803-EG). To summarize, the project resulted in 10 conference presentations and publications and one refereed journal publication. For NPS it resulted in one Ph.D. thesis (King, R. L.), one Engineer's degree thesis (Robinson, C. S.), two M. S. degree theses (Rafanello, S. P. and Weissenfels, R. D.), and one Ph.D. degree in work (Couch, M. A.).

PUBLICATIONS:

King, R.L., "Nonlinear Inplane Flexbeam Stiffness Provides Rotor System Stability Without Lag Dampers," *Journal of the American Helicopter Society*, Vol. 46, No. 4, pp. 283-289, October 2001.

PRESENTATIONS:

Couch, M.A. and Wood, E.R., "Exploring Methods to Incorporate Unsteady Aerodynamics into Nonlinear Rotor Dynamics Simulation," Ninth International Workshop on Aeroelasticity of Rotorcraft Systems, University of Michigan, Ann Arbor, MI, 22-24 October 2001.

THESIS DIRECTED:

Ehlers, G.E., "Hi-Fidelity Simulation and Prediction of Helicopter Single Point External Load Stabilization," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Rotorcraft, Helicopter, Ground/Air Resonance, Damperless, VTOL/Maple/Simulink

RESEARCH IN THE STRUCTURAL DYNAMIC RESPONSE OF THE RAH-66 COMANCHE HELICOPTER

E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Sponsor: Comanche Program Office

OBJECTIVE: The objective of this proposal in the present task calls for structural optimization of the Comanche tailcone against 23-MM HEI threat. There are two phases to this work. One phase consists of correlation of our DYSTRAN simulation with results of live fire tests conducted at Aberdeen Proving Ground on the tailcone fabrication under the STA (Static Test Article) phase of the program. The second phase consists of exploring the integrity of the EMD design of the RAH-66 to the 23 MM HEI threat. In effect, the STA phase serves as verification of DYTRAN modeling compared to real world firing tests. The EMD phase is being conducted to improve the design strength of the tailcone.

SUMMARY: Work on the DYTRAN project was completed in the spring of '01. At that point the Army asked NPS to change the focus of this research to aeroacoustics. Specifically NPS was asked to take an existing Army program for aural detection of helicopters that had been coded in Fortran and to rewrite this program in a modern, computer friendly language, and also include in the new version updates from other aural detection programs to bring it up to state-of-the-art. Much of this work is now complete. Professor Wood assisted by Associate Professor Steve Baker of the NPS Physics department and MAJ Ron Selvy (USMC) are in the process of completing the work. They have taken the previous code (ICHIN) which stands for "I can hear it now" and developed a new code in Matlab. The new code is named MICHIN, where the added M signifies Matlab. Army plans call for sound jury tests to be done in the fall to verify MICHIN.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Helicopter, Rotorcraft, Dynamics, Structures, NASTRAN/DTRAN

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

2001
Faculty Publications and Presentations

JOURNAL ARTICLES

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Chandrasekhara, M.S., Wilder, M.C. and Carr, L.W., "Compressible Dynamic Stall Control: Comparison of Two Approaches," (Invited AIAA Paper 99-3122), *Journal of Aircraft*, Vol. 38, No. 3, pp. 448-453, May-June 2001.

Fahroo, F. and Ross, I.M., "Costate Estimation by a Legendre Pseudospectral Method," *Journal of Guidance, Control and Dynamics*, Vol. 24, No. 2, pp. 270-277, March-April 2001.

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Agrawal, B. and Senenko, C., "Attitude Dynamics and Control of Bifocal Relay Mirror Spacecraft," AAS 01-418, AAS/AIAA Astrodynamics Specialist Conference, Quebec City, Canada, 30 July–2 August 2001.

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Castro, B.M., Jones, K.D., Ekaterinaris, J.A. and Platzer, M.F., "Analysis of the Effect of Porous Wall Interference on Transonic Airfoil Flutter," AIAA-2001-2725, 31st AIAA Fluid Dynamics Conference and Exhibit, Anaheim, CA, 11-14 June 2001.

Chen, H., Agrawal, B., Longman, R., Phan, M. and Edwards, S., "Rejection of Multiple Unrelated Periodic Disturbances Using MELMS with Disturbance Identification," AAS/AIAA Space Flight Mechanics Meeting, Santa Barbara, CA, 11-15 February 2001.

Chen, H., Agrawal, B. and Longman, R., "Approaches to Matched Basis Function Repetitive Control," AAS-01-369, AAS/AIAA Astrodynamics Specialist Conference, Quebec City, Canada, 30 July–2 August 2001.

Couch, M. and Wood, E.R., "Exploring Methods to Incorporate Unsteady Aerodynamics into Nonlinear Rotor Dynamics Simulations," 9th International Workshop on Aeroelasticity of Rotorcraft Systems, Ann Arbor, MI, October 2001.

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Duren, R., "F/A-18 C/D Avionics Architecture Upgrade Study," F/A-18 Advanced Weapons Laboratory Combined Country Conference (AWL C^3): Building Synergies – A Look to the Future, NAWCWD, China Lake, CA, 6-7 March 2001.

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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

JEFFREY B. KNORR
CHAIR

ELECTRICAL AND COMPUTER ENGINEERING

OVERVIEW:

The Department of Electrical and Computer Engineering (ECE) has a broad research program, reflecting the variety of skills and interests of the faculty. ECE faculty research projects are supported by systems commands, warfare centers, the services, basic research agencies, other universities, and industry. These research projects can be grouped into ten major research thrust areas that support the curricula serviced by the Department as well as the several DoD Plans. Unique to the Department and the Naval Postgraduate School is the ability of faculty and students to perform military relevant classified research at all levels. The Department's research program ensures that our graduate students will have a creative and meaningful thesis experience, that our curricula and courses will remain at the cutting edge, that we can recruit and retain quality faculty, and that we can provide our sponsors with cutting edge solutions to their problems.

CURRICULA SERVED:

- Electronic Systems Engineering
- Information Warfare
- Electronic Warfare
- Space Systems Operations
- Space Systems Engineering
- Undersea Warfare
- Joint C4I Systems
- Information Technology Management
- Aeronautical Engineering

DEGREES GRANTED:

- Master of Science in Electrical Engineering
- Master of Science in Engineering Science
- Electrical Engineer
- Doctor of Philosophy

RESEARCH THRUSTS:

- Communication Systems:
  Professor Tri Ha, Professor R. Clark Robertson
- Communication Networks:
  Assistant Professor John McEachen, Professor Murali Tummala, Military Assistant Professor Robert Ives, Associate Professor Xiaoping Yun
- Computer/Information Systems:
  Professor Jon Butler, Associate Professor Douglas Fouts, Professor Herschel Loomis, Visiting Instructor Randy Wight
- Electromagnetic Systems:
  Professor Jeffrey Knorr, Research Associate Professor Richard Adler, Associate Professor David Jenn, Professor Michael Morgan, Research Associate Andrew Parker, Research Associate Professor Ray Vincent, Visiting Associate Professor Jovan Lebaric
- Infra-Red and Electro-Optics:
  Distinguished Professor John Powers, Professor Phillip Pace, Visiting Associate Professor Ron Pieper
- Guidance, Control and Navigation Systems:
  Associate Professor Roberto Cristi, Associate Professor Gary Hutchins, Associate Professor Xiaoping Yun
- Power Electronics, Electric Machines and Distribution:
  Associate Professor Robert Ashton, Associate Professor John Ciezki

- Radar, Surveillance and Information Warfare Systems:
  Professor Jeffrey Knorr, Professor Phillip Pace, Research Associate Professor Lonnie Wilson, Professor R. Clark Robertson
- Signal Processing/Acoustic Systems:
  Associate Professor Robeto Cristi, Associate Professor Monique Fargues, Associate Professor Ralph Hippenstiel, Professor Charles Therrien, Professor Murali Tummala, Professor Lawrence Ziomek
- Signals Intelligence/Space Systems:
  Associate Professor Douglas Fouts, Professor Tri Ha, Associate Professor Ralph Hippenstiel, Professor Herschel Loomis, Assistant Professor John McEachen, Associate Professor Sherif Michael, Assistant Professor Todd Weatherford
- Solid State Microelectronics:
  Associate Professor Douglas Fouts, Associate Professor Sherif Michael, Assistant Professor Todd Weatherford

RESEARCH FACILITIES:

- Signal Enhancement Lab
- Power Electronics Lab
- Digital Signal Processing Lab
- Electronics (Analog VLSI/Radiation Hardening) Lab
- Electronic Warfare Lab
- Electromagnetic Lab
- Optical Electronics Lab
- Robotics Lab
- Advanced Networking Lab
- VLSI Lab
- Secure Computing Lab

RESEARCH CENTERS:

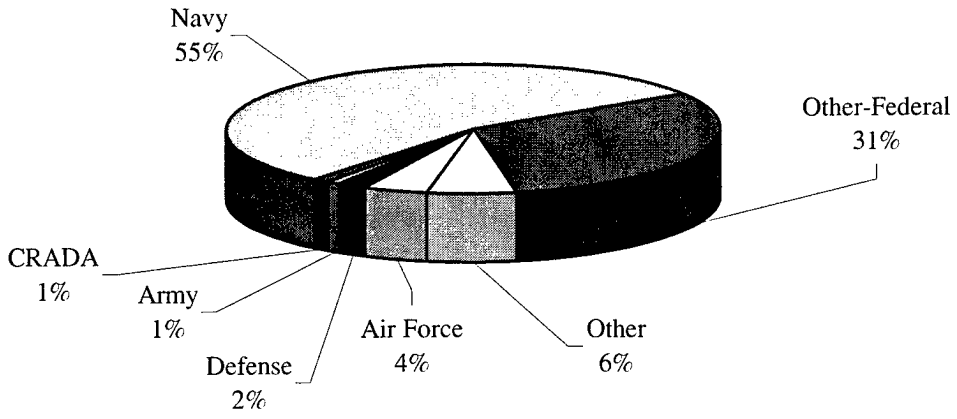
- Center for Electronic Warfare Simulation and Modeling
- Center for Reconnaissance Research
- Center for Signal Processing
- Cryptologic Research Center
- Center for Radiation Hardened Electronics

RESEARCH CHAIR:

- National Security Agency Cryptologic Chair

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 Electrical and Computer Engineering is provided below:



Size of Program: $3509K

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NOISE AND INTERFERENCE AFFECTING THE PERFORMANCE OF EXISTING AND PROPOSED COMMUNICATION SYSTEMS

Richard W. Adler, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Federal Communication Commission

OBJECTIVE: To assess and report to the FCC the current state of knowledge about the electromagnetic noise and interference that affects the performance of existing and future wireless systems.

SUMMARY: The effort involves (1) a literature survey of the noise environment and (2) a preliminary definition of the modeling, simulation and measurement requirements for evaluating the effects of the noise on communication systems.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Radio Noise, Interference, Spectrum Signatures, Bibliographies

SIGNAL-TO-NOISE ENHANCEMENT PROGRAM

Richard W. Adler, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Security Group

OBJECTIVE: To define factors that adversely affect signal reception at receiving sites, determine the primary characteristics of factors, identify all factors, and provide recommendations for effective mitigation actions.

SUMMARY: Radio noise from overhead power lines has been identified as the major factor limiting the reception of radio signals at 36 of 37 sites examined. This little recognized factor is seriously limiting the effectiveness of HF, VHF, and UHF intercept systems to collect signals of special interest. The primary properties of this noise have been defined, source location procedures have been devised, and a means to identify source hardware has been generated. This effort has generated a number of technical papers and presentations during the last year. Some related work on signal reception in the microwave ISM bands has also been conducted.

PUBLICATIONS:

Parker, A.A., Adler, R.W. and Vincent, W.R., *Conducted EMI from an Engineering Model of a DC-to-DC Converter*, Naval Postgraduate School Technical Report, NPS-EC-01-007, June 2001.

PRESENTATIONS:

Vincent, W., Adler, R. and Munsch, G., "A Review of Man-Made Radio Noise at 37 HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Munsch, G. and Adler, R., "A Progress Report on a Model for Man-Made Noise at HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Parker, A., Adler, R. and Vincent, W., "Spectrum Signatures of Man-Made Noise," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Parker, A. and Adler, R., "Ambient Signals and Noise in the 915-MHz ISM Band," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Adler, R. and Munsch, G., "Operation of a 2.4 GHz Portable Phone with Noise From a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Adler, R. and Munsch, G., "The Temporal and Spectral Properties of Radio Noise from a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

OTHER:

Parker, A., Adler, R. and Vincent, W., "Parasitic Oscillations from an Active Television Antenna," prepared in cooperation with the Department of Oceanography.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Radio Noise, Interference, Spectrum Signatures

DEVELOPMENT OF ALGORITHMS SUPPORTING HARDWARE-IN-THE-LOOP CONTROL OF SYNCHRONOUS MACHINES

Robert William Ashton, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: This research involves the creation of a DSP platform for developing and testing motor control algorithms. The platform will have hardware-in-the-loop testing capability. The Navy's interest in pursuing and electric drive solution for ship propulsion has enabled the consideration of novel approaches for controlling the inverter used for the propulsion motor. The proposed research seeks to aid in the developing tools and algorithms to support an initial reduced-scale proof-of-concept demonstration. The demonstration will utilize a three-phase permanent magnet synchronous machine powered by a conventional three-phase voltage source inverter. The investigation will execute a number of tasks, culminating in a set of deliverables.

DoD KEY TECHNOLOGY AREAS: Other (Motor Control)

KEYWORDS: PWM Inverter, Synchronous Machine, Vector Control, DSP

IMPLEMENTATION OF CLOSED-LOOP SYNCHRONOUS MACHINE CONTROL

Robert William Ashton, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The proposed research seeks to aid in hardware and software modifications to existing inverters so that various Navy motor loads may be utilized and tested. This research involves the implementation of closed-loop controls for synchronous machines utilizing multiple inverters of varying power levels to drive Navy motor loads up to 400HP. The Navy's interest in pursing an electric drive solution for ship propulsion has enabled the consideration of novel approaches for controlling the inverter used for the propulsion motor and other motor loads. The drive system will be demonstrated utilizing three-phase induction or synchronous machines powered by multiple synchronized three-phase inverters. The investigator will execute a number of tasks, culminating in a set of deliverables.

DoD KEY TECHNOLOGY AREAS: Other (Motor Control)

KEYWORDS: PWM Inverter, Synchronus Machine, Vector Control, DSP

INTEGRATED FIGHT-THROUGH POWER AND ADVANCED POWER CONVERTER MODULES

Robert William Ashton, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center - Philadelphia

OBJECTIVE: The proposed research seeks to aid in developing tools and algorithms to support an initial reduced-scale proof-of-concept demonstration.

SUMMARY: This research involves the creation of a DS platform for developing and testing motor control algorithms. The platform will have hardware-in-the-loop testing capability. The Navy's interest in pursing an electric drive solution for ship propulsion has enabled the consideration of novel approaches for controlling the inverter used for the propulsion motor. The demonstration will utilize a three-phase permanent magnet synchronous machine powered by a conventional three-phase voltage source inverter. The investigation will execute a number of tasks, culminating in a set of deliverables.

This research involves the engineering design of advanced power conversion modules under current Navy development. This task will require the investigation of available power converter design options. Additionally, assistance in the design and development of advanced reconfigurable zonal electric distribution system hardware will be provided in the form of testing, debugging and documentation. Support includes conducting appropriate tests, analyzing/evaluating technical documentation/data, and providing comments. The principal investigator shall attend technical meetings, as required, and provide monthly status reports. Travel to CDNSWC-SSES Philadelphia shall be required to implement the above objectives.

This research concentrated on specific issues surrounding the Land Based Engineering Site (LBES) in Philadelphia. The investigator was tasked with the evaluation of data from test runs for a number of Power Converter Modules (PCM) ranging from 250kW to 19MW. Test results were analyzed and used by the investigator to aid in making recommendations for future PCMs. In addition, three specific failure events took place on the 19MW PWM electric drive unit. Each event was analyzed using the available data including forensics on the components. Reports and presentations were made in Philadelphia and Rugby, England. The results of the investigation have been utilized in redesign efforts by the vendor.

DoD KEY TECHNOLOGY AREAS: Other (Electronic Devices, Energy Conversion)

KEYWORDS: Power System, Auxiliary Resonant Commutated Pole Inverter, PWM Inverter, Sychronous Machine, Vector Control, DSP

DESIGN ALGORITHMS FOR SUM-OF-PRODUCTS EXPRESSIONS

Jon T. Butler, Professor
Department of Electrical and Computer Engineering
Tsutomu Sasao, Kyushu Institute of Technology, Japan
Sponsor: Unfunded

OBJECTIVE: To produce design algorithms for digital logic circuits using sum-of-products expressions.

SUMMARY: The design of many logic circuits relies on the simplification of sum-of-products expressions that describe the function realized by the circuit. Efforts this year focused on three aspects of this problem. First, work continued from last year on bi-decomposition of functions. Last year, orthodox functions were identified as a special class of functions for which an efficient divide-and-conquer algorithm produces minimal sum-of-products expressions. This year, collaborative work with NPS Master's student, Birol Ulker, identified families of non-orthodox functions in. Second, shared binary decision diagrams (SBDDs) were successfully applied to multi-output functions, and it was shown that this results in an improvement in circuit compactness of 16%, on the average, over standard binary decision diagram techniques. Third, a new type of programmable logic device was proposed and a study of efficient algorithm for these devices has been initiated. This is collaborative work with Professor Tsutomu Sasao of the Kyushu Institute of Technology.

PUBLICATIONS:

Matsuura, M., Sasao, T., Butler, J.T. and Iguchi, Y., "Bi-partition of Shared Binary Decision Diagrams," Workshop on Synthesis and System Integration of Mixed Technologies (SASIMI-2001), pp. 172-177, Nara, Japan, 18-19 October 2001.

Sasao, T. and Butler, J.T., "Worst and Best Sum-of-Products Expressions," *IEEE Transactions on Computers*, pp. 935-948, September 2001.

Sasao, T. and Butler, J.T., "On the Minimization of SOPs for Bi-Decomposable Functions," ASP-DAC (Asian Southern Pacific Design Automation Conference), pp. 219-224, Yokohama, Japan, February 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Digital Systems, Compact Circuits, Computer-Aided Design Tools, Sum-of-Products Expressions

REED-MULLER CANONICAL EXPANSIONS OF LOGIC FUNCTIONS

Jon T. Butler, Professor
Department of Electrical and Computer Engineering
G.W. Dueck, University of New Brunswick, Canada
Sponsor: Unfunded

OBJECTIVE: To improve synthesis techniques for the Reed-Muller canonical representation of logic function.

SUMMARY: The Reed-Muller canonical expansion of a logic function uses the Exclusive OR of product terms, where each product term is the AND of variables or their complements. It has been shown that this representation requires fewer product terms, on the average, than standard sum-of-products expressions. The transeunt triangle concept that was introduced earlier has been extended to efficiently realize totally symmetric functions so that it also applies to partially symmetric functions. Efforts have also been expanded to the more general "inconsistent" expansion of functions proposed more than 30 years ago by Martin Cohn. In a collaborative effort with NPS student, Panos Michalopoulos, progress has been made in the understanding of the largest size one can possibly expect of functions in this form.

PUBLICATIONS:

Butler, J.T., Dueck, G.W., Yanushkevich, S.N. and Shmerko, V.P., "On the Number of Generators for Transeunt Triangles," *Discrete Applied Mathematics*, Vol. 108, pp. 309-316, 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Digital Systems, Compact Circuits, Computer-Aided Design Tools, Exclusive OR Sum-of-Products Expressions, Reed-Muller Canonical Expressions

COMPONENT MODELING AND SIMULATION EFFORTS FOR A PROPOSED LHD-8 AC ZONAL DISTRIBUTION SYSTEM

John G. Ciezki, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The Navy is currently designing the next-generation LHD amphibious ship. Innovations are being proposed for the power distribution system, including zonal AC and a hybrid electric drive. Models of the components and interconnected system topologies are required to analyze the system for

fault performance, stability, circuit breaker response, and the design of paralleling controls. The enclosed effort requires the development and integration of component-level models into an existing AC zonal distribution package. Specifically, the existing package will be reviewed for syntax and interconnection format. Models for the diesel generators, delta-delta 3-phase transformers, synchronous machines, and associated controls will be formulated. Interconnection requirements will be documented.

SUMMARY: A literature search was conducted regarding diesel engine modeling and several strategies were investigated. Modeling equations for the delta-delta transformers and conventional three-phase synchronous machines were formulated. An interconnection strategy was developed based on Mayer's approach of root and non-root models. Control development software was written to aid in the tuning of exciter parameters. Woodward control diagrams were consulted for current topologies. Software implementation was hampered by UNIX system incompatibilities and system administrator delays. Work continues on delivering operational models.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: AC Zonal Distribution, Diesel Generators, Transformers, ACSL Simulation

DETAILED FAULT CHARACTERIZATION FOR SHIPBOARD POWER SYSTEMS

John G. Ciezki, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The performance of Navy shipboard power systems during casualty situations is critical in assessing survivability and in formulating improved condition monitoring hardware and control algorithms. Power system damage inflicted by mines, air-to-surface missiles, and other projectiles is manifested in various types of cable short circuits and open circuits. The damage can appear intermittently and it can cascade if monitoring systems are not able to isolate fault locations quickly. The purpose of this work is to develop computer representations of various fault scenarios and match the models to acquired test facility data. This effort entails modeling the test facility generator, developing circuit equations to represent line-line and various fault conditions, including both low impedance and high impedance faults, and modifying the fault impedance representation in a time-varying fashion in order to match the collected data.

SUMMARY: A literature review was conducted on techniques used for characterizing time-varying fault impedances. Parameters for the synchronous machine test facility were calculated via test data information. Equations were developed modeling single-phase, phase-to-phase, and three-phase faults for a conventional three-phase machine. Studies were devised for contrasting the ACSL simulations with available KEMA test data. Simulations results have been delayed due to the inability of UNIX administrators to install and get the ACSL software running. Work continues on providing useful deliverables.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: Fault Analysis, AC Generators, ACSL Simulation

SYMBOLIC MATHEMATICS FOR ON LINE TESTING

Roberto Cristi, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Unfunded

OBJECTIVE: The purpose of this research is to develop tools for on line testing techniques which are not multiple choice. This will benefit courses in the Applied Sciences areas (Engineering, Mathematics, Physics), where the answers of the students are formulated in terms of mathematical symbols.

SUMMARY: The use of symbolic evaluation software, such as Mathematica, provides the necessary engine for evaluating and assessing the student's responses. The outcomes of this research are presented in J. Biggs' master's thesis and a Website (http://pclearn.ece.nps.navy.mil) of a Digital Signal Processing Course (EC2400, currently in the NPS catalog) has been developed. In J. Biggs' thesis, a general architecture for on-line course development is presented. In particular it is shown that by a combination of a number of software tools (JSP, Servlets, Mathematica, WebMathematica and Access), an on-line course can be developed which is capable not only of evaluating student's answers entered in symbolic form, but also of tracking the student's performance in the course. The latter is achieved by a dynamic test, which adapts the questions in the exams to the student's performance. According to this scheme, the student is evaluated on the basis of a number of trials necessary to answer a number of similar questions. In this way the evaluation is not binary (just right or wrong) and it rules out the possibility of guessing. The software developed is also capable of delivering coursework material, keep track of student enrollment, and appropriately schedule tests for the students.

THESIS DIRECTED:

Briggs, J., "Web Testing Tools for Electrical Engineering Courses," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: On-line Course, Digital Signal Processing

FEATURE EXTRACTION FOR SIGNAL CHARACTERIZATION IN CLASSIFICATION APPLICATIONS: APPLICATIONS TO COMMUNICATION MODULATION

Monique P. Fargues, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Center for Reconnaissance Research

OBJECTIVE: This study completed an on-going research effort investigating various feature extraction schemes and applications to the classification of digital signal modulation types.

SUMMARY: The study conducted during FY01 concluded an on-going research effort investigating feature extraction schemes and applications to the classification of digital modulation schemes. The study was split into two phases.

First, a hierarchical tree-based classification approach was considered to the classification of digital modulation schemes of types [2,4,8]-PSK, [2,4,8]-FSK and [16,64,256]-QAM in low SNR levels and multipath propagation channel conditions, where back-propagation neural network units were adopted at each tree node. Higher-order statistics-based class features were investigated and a small number of cumulants and moments chosen to differentiate between all various types of modulation types, except for specific M-QAM types. While being part of the hierarchical procedure, the identification of specific M-QAM types was conducted via equalization algorithms. Extensive simulations show overall classification performances to be strongly affected by the amount of multipath distortion and noise in the transmission channels.

The second phase of the study investigated three discriminant-based feature dimension reduction schemes: the Mean Separator Neural Network (MSNN), the Mahalanobis-based Dimension Reduction scheme (MBDR), and the kernel-based Generalized Discriminant Analysis (GDA) approach. PCA was also included for comparison purposes. All four feature dimension reduction schemes were implemented and evaluated by applying the transformed features to a basic minimum distance classifier. Three classification datasets commonly used in statistics for benchmarking purposes were selected for benchmarking purposes. Results showed the kernel-based generalized discriminant analysis approach to lead to consistently higher classification performances than the other schemes considered in the study for the data investigated.

PUBLICATIONS:

Fargues, M.P. and Hatzichristos, G., "A Hierarchical Approach to the Classification of Digital Modulation Types in Multipath Environments," *Proceedings of the 35th Asilomar Conference on Signals, Signals, and Computers*, November 2001.

Fargues, M.P., *Investigation of Feature Dimension Reduction Schemes for Classification Applications*, Naval Postgraduate School Technical Report, NPS-EC-01-005, June 2001.

Fargues, M.P. and Hatzichristos, G., *A Hierarchical Approach to the Classification of Digital Modulation Types in Multipath Environments*, Naval Postgraduate School Technical Report, No. NPS-EC-01-004, May 2001.

THESIS DIRECTED:

Hatzichristos, G., "Classification of Digital Modulations in Multipath Environments," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREAS: Electronics, Computing and Software

KEYWORDS: Classification, Higher-Order Statistics, Kernel Method

DETECTION, CLASSIFICATION AND PROCESSING OF WIRELESS LOCAL AREA NETWORK SIGNALS

Tri T. Ha, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Information Warfare Activity

OBJECTIVE: Develop a prototype using commercially available low cost hardware and software solutions to detect, classify and process a wireless IEEE 802.11b DSS compliant network signal.

SUMMARY: There were routine interactions (through phone conversations, email, meetings, etc.) with the staff, students, government agency and contractor personnel involved in this NIWA sponsored project. This research focuses on developing a prototype system that will allow the detection and process WLAN signals in real time. The prototype system was developed using commercial software and hardware components that can be upgraded and enhanced as the industry standard changes. The research includes the methodology used in selecting the commercial software and hardware components. In addition substantial testing results are included that outline the conditions under which the prototype will be able to receive and process 802.11b WLAN signals. The measured data is compared to radio frequency propagation models, and a simple formula to determine if a signal can be detected is presented. The research concludes with recommendations on how to successfully employ the system in an operational environment.

DoD KEY TECHNOLOGY AREAS: Other (Information Operations, Electrical Engineering)

KEYWORDS: WLAN, Propagation Model, Wireless

NSA/ATD CRYPTOLOGIC RESEARCH LAB AND THESIS RESEARCH SUPPORT

Tri T. Ha, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

OBJECTIVE: Support for the Cryptologic Research Lab at the Naval Postgraduate School wherein graduate students perform research in support of ATD (formerly K51).

SUMMARY: The Cryptologic Research Laboratory, sponsored by the National Security Agency's ATD, is a valuable resource which provides a cost effective, viable and robust research platform for NPS graduate students and faculty in Electrical Engineering, Information Warfare, and Computer Science and related curricula. It offers an unclassified environment wherein graduate students can develop an in-depth understanding of cryptology and related disciplines by researching capabilities, limitations, design, and operations of digital signal processing and exploitation techniques, satellite communications technologies, cellular technologies, wireless communications and other analogous cryptologic areas.

THESES DIRECTED:

Halloran, S.P., "Vulnerability Assessment Through Predictive Modeling of IEEE 802.11 Standard Wireless Local Area Networks," Masters Thesis, Naval Postgraduate School, June 2000.

Myers, W.S., "Exploitation of an IEEE 802.11 Standard Wireless Local Area Network Through the Medium Access Control (MAC) Layer," Masters Thesis, Naval Postgraduate School, June 2000.

Oubre, D.I., "Capabilities and Limitations of Orthogonal Frequency-Division Multiplexing in Wireless Applications," Masters Thesis, Naval Postgraduate School, September 2000.

Harrell, A.T., "Wireless Technology Via Satellite Communications for Peacekeeping Operations," Masters Thesis, Naval Postgraduate School, September 2000.

Yokoyama, M.K., "Airborne Exploitation of an IEEE802.11b Wireless Local Area Network," Masters Thesis, Naval Postgraduate School, September 2000.

Count, P.A., "Performance Analysis of OFDM in Frequency Selective, Slowly Fading Nakagami Channels," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Other (Information Operations, Electrical Engineering)

KEYWORDS: Cryptology, Exploitation, Wireless

IMPROVEMENT OF THE SIGNAL-TO-NOISE RATIO USING WAVELET RELATED SIGNAL PROCESSING

Ralph D. Hippenstiel, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Center for Reconnaissance Research

OBJECTIVE: Investigate wavelet related processing and scale/time tiling to improve the effective SNR of signatures of interest.

SUMMARY: The work investigates the improvement of the estimate of signals which are embedded in white Gaussian noise. The first part evaluates the use of a wavelet based decomposition to denoise signals. The denoising is achieved in the wavelet domain using i) median and ii) predictive filtering. The second part focuses on the use of Fourier transform based denoising, where the denoising is applied in the time-frequency domain. The denoising uses median or predictive filtering. Improvement is measured using the mean square error.

THESES DIRECTED:

Hughes, J., "Signal Enhancement Using Time-Frequency Based Denoising," Masters Thesis, Naval Postgraduate School, in progress.

Kan, H.E., "Signal Enhancement," Masters Thesis, Naval Postgraduate School, in progress.

DoD KEY TECHNOLOGY AREA: Electronics

KEYWORDS: Signal Enhancement, Signal Classification, Wavelet Based Decomposition, Denoising, Time-Frequency Based Filtering

DEFENSE TECHNOLOGY AND SYSTEMS COURSE

David C. Jenn, Associate Professor
Department of Electrical and Computer Engineering
Sponsors: National University of Singapore

OBJECTIVE: Generate and deliver a comprehensive set of lectures that cover the topics of basic electromagnetics, transmission lines, antennas, propagation, scattering, radar, jamming, and sensor integration and fusion. Design a set of computer based laboratory exercises based on the lecture material. The total length of the course is four days and two exams are given to evaluate student performance.

SUMMARY: Lecture notes were based on the material in NPS courses EO2652, EO3602 and EO4612. The notes were initially generated for last year's course, but significant modifications were required for this year's course. The course also uses a set of Matlab based computer exercises for instruction in each of the topic areas.

PUBLICATIONS: "Sensors," 13 volume set of lecture notes (352 pages) in PDF format.

PRESENTATIONS: DTSC lectures and laboratory supervision (4 days).

DoD KEY TECHNOLOGY AREA: Electronic Warfare, Sensors, Electronics

KEYWORDS: Antennas, Electromagnetics, Sensors

EFFECTIVENESS OF BROADBAND ANTENNA DESIGNS

David C. Jenn, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: QRC, Inc.

OBJECTIVE: Several broadband antenna designs were evaluated for use in a ground penetrating radar for buried ordinance detection.

SUMMARY: A combination of measurement, analysis, and simulation was used to evaluate several antennas for use in a ground penetrating radar for the detecting buried ordinance (mines and unexploded bombs). Candidate antennas included the contra-wound helix, contra-wound log-periodic spiral and a sinuous cavity backed slot. A method-of-moments computer code was used to evaluate the antenna input impedance and near field patterns.

PUBLICATION:

Jenn, D.C. and Wollny, W.T., "Broadband Focused Radar at Ground Penetrating Frequencies for Detecting Mines," Final Report submitted to Army Research Office, Mechanical and Environmental Sciences Division, Engineering Sciences Directorate, November 2001.

PRESENTATION:

Jenn, D.C. and Wollny, W.T., "Broadband Antenna Study for Buried Object Detection," Army Research Office, Ft. Belvoir, 12 October 2001.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics

KEYWORDS: Antennas, Electromagnetics, Sensors

HELICOPTER PAYLOAD PHASE 1 ANTENNA STUDY

David C. Jenn, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this study was to determine the optimum antenna placement given the available locations on the helicopter. The suitability of a location is determined by the quality of the antenna pattern, primarily field-of-view, which is defined as the range of angles over which the antenna gain is constant enough and/or sufficient enough to permit signal reception regardless of the direction of flight.

SUMMARY: An analysis and simulation of the antenna installed on the helicopter was conducted using computational electromagnetics (CEM) codes. The simulated pattern data for the installed antenna was compared to that of the free standing antenna, which is used as a baseline from which to determine the effects of the antenna placement on signal reception. If the installed antenna pattern deviates significantly from the baseline antenna pattern, then the reception is potentially degraded. The frequency range of interest was 100 MHz to 1200 MHz.

PUBLICATION:

Jenn, D.C., *Helicopter Payload Phase 1 Antenna Study*, Naval Postgraduate School Technical Report, NPS-EC-01-008, October 2001.

PRESENTATION:

Jenn, D.C., "VTUAV Phase 1 Antenna Study Results," VTUAV Program Review, Northrop-Grumman-Ryan Aerospace, San Diego, CA, 21 June 2001.

DoD KEY TECHNOLOGY AREA: Electronic Warfare, Sensors, Electronics

KEYWORDS: Antennas, Electromagnetics, Sensors

DAR REMOTE SENSING

Jeffrey B. Knorr, Professor
Department of Electrical and Computer Engineering
Bob Bluth, Research Associate
Center for Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to acquire and modify two military radars for meteorological research.

SUMMARY: An Army AN/MPQ-64 Sentinal radar was acquired in the Spring of 1999 and was brought to operational status during the Fall of 1999 and the Winter of 2000. An SBIR project, N01-035, Weather Processor for Rapid Scanning Tactical Radars, was initiated with ProSensing, Amherst, MA to add a Doppler processor to the radar for severe storm research. During May 2001, a meeting was held with ProSensing engineers to discuss details associated with the addition of the weather processor. It is expected that initial testing of the processor will take place during 2002.

During 2000 steps were also taken to obtain an Army AN/TPQ-37 Firefinder radar. A radar was delivered in the Spring of 2001 but the Army subsequently requested that the radar be returned to satisfy

another requirement and it was relinquished in the Fall of 2001. The AN/TPQ-37 radar is similar to the AN/SPY-1 radar installed on the Navy's Aegis cruisers and destroyers. A project was planned to add a weather processor to this radar so it could be used as a testbed for investigation of AN/SPY-1 algorithms to extract meteorological data. This goal must now await the acquisition of another AN/TPQ-37 radar.

The overall long term objective of this project is to develop radar remote sensing capabilities that will provide meteorological data that can be used to describe weather phenomena, particularly in support of air operations in the fleet battlespace.

PRESENTATION:

Knorr, J.B., Bluth, R. and Pazmany, A., "Rapid Scan 3D Volumetric Weather Radar," 30th International Conference on Radar Meteorology, Munich, Germany, 14-19 July 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Remote Sensing, Radar Meteorology

ANTENNA DEVELOPMENT FOR MAN-PACK TACTICAL RADIOS

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: U.S. Army Soldier Biological Chemical Command

OBJECTIVE: The objective is to improve the design a conformal, wearable RF vest antenna for low VHF, and to design a compact antenna for a hand-held field radio operating in the 30 to 88 MHZ band.

SUMMARY: The research, development and design will be accomplished by optimizing the antenna and feed region shape, adding commercially available cladding material in the feed region, and integrating the RF vest with the Kevlar flak vest. The feed region cladding and shaping will reduce the near-field coupling to the operator and increase the antenna efficiency. The compact antenna design will be directed towards using dielectric and resistive loading to reduce the antenna VSWR while maintaining antenna radiation efficiency as high as possible.

PUBLICATION:

Lebaric, J., Adler, R.W. and Limbert, M., "Ultrawideband, Zero Visual Signature RF Vest Antenna for Man-Portable Radios," MILCOM 2001, McLean, VA, 28-31 October 2001.

PRESENTATION:

Lebaric, J., Adler, R.W. and Limbert, M., "Ultrawideband, Zero Visual Signature RF Vest Antenna for Man-Portable Radios," MILCOM 2001, McLean, VA, October 2001.

OTHER:

The NPS IP counsel has been informed that patent for "The Wearable Ultrawideband Vest Antenna" will be issued by the USPTO within a couple of months.

THESIS DIRECTED:

Limbert, M., "Ultrawideband Combat Wearable Integrated (COMWIN) Antenna Design for the Joint Tactical Radio System (JTRS)," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Communications, Antennas

DESIGN AND PROTOTYPING OF WIDEBAND USQ-113 ANTENNA FOR EA-6B

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Andrew Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: Naval Air Systems Command

OBJECTIVE: Design and prototype an ultrawideband antenna for the USQ-113 system onboard EA-6B aircraft, such as to meet the specifications, especially height imposed by the operational aircraft use (carrier landing and take-off).

SUMMARY: This design is an evolution of the "bell" antenna design tested at NPS in FY99. The new design has a reduced height and weight, a modified shape, and addition of new elements. The design is a compromise between the optimal electrical performance for a given height constraint and the aerodynamic constraint of the high-speed platform the antenna is intended for.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Information Warfare, Jamming, Antennas

HELMET MOUNTED UHF ANTENNA FOR SATELLITE COMMUNICATIONS

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective is to design a satellite communications antenna for integration with a standard-issue U.S. military helmet, within DoD Instruction 605.11 defined parameters.

SUMMARY: The objective will be accomplished using a conformal two-arm spiral antenna design for circular polarization. The spiral will be embedded in a protective layer that would also increase the electrical length of the antenna. A shorted ring will be added at the bottom of the conformal two-arm spiral to improve the front-to-back ratio and reduce the operator near-field exposure below the levels specified in the DoD 605.11 standard.

THESIS DIRECTED:

Gibbs, D., "Design of Mobile User Objective System (MOUS) Helmet Mounted UHF Antenna," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Satellite Communications, Antennas

USQ-146 LOW-PROFILE OMNI-DIRECTIONAL ULTRA-WIDEBAND ANTENNA FOR SHIPBOARD AND VEHICULAR USE

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Information Warfare Activity

OBJECTIVE: The objective is to design a low-profile omni-directional ultrawideband antenna for the USQ-146 system. The antenna will be installed on land-based vehicles or onboard ships.

SUMMARY: The antenna design is based on the mono-conical antenna with matched loading to reduce the antenna VSWR at the low end, with minimum reduction in antenna efficiency throughout the operating frequency range. Also, the design allows for increasing the antenna height using elements stowed inside the cone and deployed "on-demand."

THESIS DIRECTED:

Koutras, N., "Ultra-Wideband Antenna Designs for Military Vehicle Applications," Masters Thesis, Naval Postgraduate School, March 2001.

OTHER: Patent application submitted to NPS IP Counsel.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Information Warfare, Jamming, Antennas

USQ-146 LOW-PROFILE QUADRANT-SWITCHABLE-BEAM ULTRA-WIDEBAND ANTENNA FOR SHIPBOARD AND VEHICULAR USE

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Information Warfare Activity

OBJECTIVE: The objective is to design a low-profile ultra-wideband transmit antenna with steerable beams for the USQ-146 Rubicon system. The antenna would be used in a shipboard environment or land-based vehicle.

SUMMARY: The design objectives will be accomplished by employing a mono-cone and bi-cone designs with special loading such that directional properties are obtained. Mechanical rotation of the loading element provides for beam steering. The directivity is a function of frequency, above 10 dB from most of the operating range. The loading material can have a loss component added for the "out-of-band" RCS reduction.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Information Warfare, Jamming, Antennas

ULTRA-WIDEBAND ANTENNA FOR THE USQ-146 INSTALLATION IN THE H-60 HELICOPTER

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Andrew Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: Naval Information Warfare Activity

OBJECTIVE: The objective is to design, fabricate and test an ultra-wideband transmit antenna for the USQ-146 installation in the H-60 helicopter.

SUMMARY: The platform operational restrictions on landing and take-off restrict the design to a height of only 10 inches while the operational requirements call for an ultrawideband antenna capable of efficient operation at low frequencies where the permissible antenna height becomes a very small fraction of the operating wavelength. Several approaches have been investigated. One approach led to an antenna design such that the antenna is mechanically rotated into the operating position from a stowed position that satisfies the height constraint. Another design is currently under development for an ultrawideband antenna with no moving parts.

THESIS DIRECTED:

Adams, J., "Ultrawideband Antenna Design for the USQ-146 Installation for the H-60 Helicopter," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Information Warfare, Jamming, Antennas

DESIGN OF A CLASSIFIED COMMUNICATIONS SATELLITE SYSTEM

Herschel H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering and Space Systems Academic Group
Sponsor: Hughes Space and Communications

OBJECTIVE: To provide technical support to a design effort for a government communications satellite system.

SUMMARY: Provided technical support to the design of the communications waveform design and concept of operations of a classified communications satellite system for the U. S. government.

DoD KEY TECHNOLOGY AREAS: Other (Information Superiority)

KEYWORDS: Communications Satellite, Communications Waveform Design

NSA/C4 COMPUTER NETWORK RESEARCH LABORATORY AND THESIS RESEARCH

Herschel H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering and Space Systems Academic Group
CAPT James Powell, USN
Department of Information Science
Sponsor: National Security Agency

OBJECTIVE: This effort will continue and expand and enhance the capabilities and research focus of the computer network research laboratory.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Network, Security, Computer, Software, Information Operations

NAVAL SIMULATION SYSTEMS CRYPTOLOGIC STUDIES

Hershel H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering and Space Systems Academic Group
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: NPS will provide a tailored technical update to the 04/05 mid-career CNSG course to meet schedule and educational requirements.

SUMMARY: The course was taught at CNSG headquarters (HQ) from 5-9 February 2001. The course will cover technical aspects of signals intelligence (SIGINT) to include an understanding of SIGINT concepts, information assurance and information operations. The course addressed difficult technical concepts as themes. Each theme provides the cryptologist the essence of the area of study. Three basic themes were selected to focus and organize the topics of instruction.

DoD KEY TECHNOLOGY AREAS: Other (Information Superiority)

KEYWORDS: Signals Intelligence

PROJECT GUSTY ORIOLE

Hershel H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering and Space Systems Academic Group
RADM Thomas C. Betterton, USN (Ret), Naval Space Technology Chair
Alan Ross, Navy Tactical Exploration of National Capabilities (TENCAP) Chair Professor
Space Systems Academic Group
Sponsor: Secretary of the Air Force

OBJECTIVE: To conduct research into architectures and algorithms for the acquisition, processing, and communication of tactical information. To provide support for the course Space Systems 3001, Military Applications of Space and SS4051, Military Space Systems and Technologies.

SUMMARY: Completed work on the following tasks: a) Developed plans for a Satellite Communications System, which has been funded through Boeing Space Systems. b) Triple-modular-redundancy computer designs completed for 64-bit microprocessor and for DSP COTS ASIC. Continued service on Ph.D. committee for NRL code 8000 employee on modeling of behavior of microprocessors in Single Event Effect environment. c) Began book *Emitter Geolocation* in collaboration with Dr. Michael Price. d) Supported Courses SS 3001 & SS4051 by the development of geolocation material and the arrangement of field trips to visit contractor sites. e) Attended meetings of government LPI Communications Committee; hosted 2-day meeting of committee at NPS in January 2001.

PUBLICATIONS:

Miller, J.B., McEachen, J.C., Loomis, H.H., Tope, M.A. and Copeland, D.B., "An Analysis of Noise in Timing-based Communications over LANs," accepted by ISCAS 2002, the IEEE International Symposium on Circuits and Systems.

Loomis, H.H., *Geolocation of Electromagnetic Emitters*, Naval Postgraduate School Technical Report, NPS-EC-00-003, January 2001 (revised edition).

THESES DIRECTED:

Ecken, H.B., "Feasibility Analysis and Design of a Fault Tolerant Computing System: A TMR Microprocessor System Design of 64-Bit COTS Microprocessors," Masters Thesis, Naval Postgraduate School, March 2001.

Wukich, M.J., "Using Commercial Off The Shelf (COTS) Digital Signal Processors (DSP) for Reliable Space Based Digital Signal Processing," Masters Thesis, Naval Postgraduate School, March 2001.

Johnson, J.J., "Implementing the Cross Ambiguity Function and Generating Geometry-Specific Signals," Masters Thesis, Naval Postgraduate School, September 2001.

Dorcey, C.T., "FFT-Based Spectrum Analysis Using a Digital Signal Processor," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors

KEYWORDS: Space-based Reconnaissance, Signals Intelligence

SECURITY VULNERABILITIES OF WIRELESS PROTOCOLS

John McEachen, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: Perform research into the internal protocols of wireless computer networks and identify vulnerabilities associated with their standard implementation. Examine use of cellular-based protocols such as Mobitex and CDPD for data communications. Begin investigation into the interface of wireless networks with landline IP networks in the interest of examining upcoming technologies such as WAP and IP telephony.

SUMMARY: Interest in portable, high-bandwidth digital communications methods spans the world and presents a formidable challenge to the Defense Department of the United States. While anxious to use new communications equipment, the armed services are wary of the vulnerabilities they expose. This project examines the vulnerability of wireless local area networks (WLANs) when used by tactical units in an urban setting. Initial efforts on this project consisted of the development of a baseline IEEE 802.11a computer simulation using OPNET. These models have been highly praised and are already in use by organizations such as Philips Electronics and BDM. More recent efforts have focused on the stand-off detection ranges of WLANs. This project also has identified several denial of service issues in the IEEE 802.11 control and management functions.

PUBLICATIONS:

McEachen, J.C. and Cay, A., "Queue Response of Correlated Traffic Insertion in ATM Networks," *IEEE Transactions in Networking*, in review.

McEachen, J.C. and Cay, A., "Connection Utilization Masking in ATM Networks," *International Journal on Information Security*, in review.

Tope, M.A. and McEachen, J.C., "Unconditionally Secure Communcations over Fading Channels," *Proceedings of the 2001 IEEE Military Communications International Symposium (MILCOM 2001)*, Washington, D.C., October 2001.

Mullin, S.C. and McEachen, J.C., "Vulnerabilities in Multiprotocol Label Switching Label Distribution," *Proceedings of the 2001 IEEE Military Communications International Symposium (MILCOM 2001)*, Washington, D.C., October 2001 (classified publication).

Braswell, B.E. and McEachen, J.C., "Modeling Data Rate Agility in the IEEE 802.11a WLAN Protocol," *Proceedings of OPNETWORK2001*, Washington, D.C., August 2001.

Braswell, B.E., McEachen, J.C. and Batson, M.S., "A Baseline Model for IEEE 802.11a WLAN Protocol," *Proceedings of OPNETWORK2001*, Washington, D.C., August 2001.

McEachen, J.C. and Cay, A., "Masking Compressed Video Connection Utilization in ATM Networks," *Proceedings of the 2001 IEEE International Symposium on Circuits and Systems (ISCAS 2001)*, Vol. V, Sydney, Australia, pp. 145-148, May 2001.

McEachen, J.C., Ow, K.C. and Lim C.T., "A System Level Description and Model of Signaling System No. 7," *Proceedings of the 2001 IEEE International Symposium on Circuits and Systems (ISCAS 2001)*, Vol. IV, Sydney, Australia, pp. 258-261, May 2001.

McEachen, J.C., *Route Intervention in Packet Networks*, Naval Postgraduate School Technical Report, NPS-EC-01-009, May 2001 (Classified Top Secret/SCI).

McEachen, J.C. and Braswell, B., *Vulnerabilities in Control and Management Functions of IEEE 802.11Wireless LANs*, Naval Postgraduate School Technical Report, NPS-EC-01-001, February 2001.

PRESENTATIONS:

McEachen, J.C., "Computer Networking in the Department of Defense," lecture to Introductory Engineering Class, Santa Clara University, 8 November 2001.

McEachen, J.C., "Teaching with OPNET," OPNETWORK2001, Washington, D.C., 30 August 2001.

THESES DIRECTED:

Mallory, P.L., "Extending IEEE 802.11b Wireless Local Area Networks to the Metropolitan Area," Masters Thesis, Naval Postgraduate School, December 2001.

Geissler, W.K., "Exploitation of Transmission Control Protocol Error Handling as a Means of Covert Communications," Masters Thesis, Naval Postgraduate School, September 2001.

Maloy, R.C., "Performance Metrics for an ATM Network Using Local Area Network Emulation (LANE) and Switched Ethernet," Masters Thesis, Naval Postgraduate School, September 2001.

Kinney, A.C., "Analysis of M-JPEG Video over an ATM Network," Masters Thesis, Naval Postgraduate School, June 2001.

Braswell, B.E., "Modeling Data Rate Agility in the IEEE 802.11a Wireless Local Area Networking Protocol," Masters Thesis, Naval Postgraduate School, March 2001.

Mullin, S.C., "Vulnerabilities of Multiprotocol Label Switching," Masters Thesis, Naval Postgraduate School, March 2001.

Tan, K.C., "Development and Simulation of the IEEE 802.11a Physical Layer in a Multipath Environment," Masters Thesis, Naval Postgraduate School, March 2001.

Chua, G.H., "An Architecture for Analysis and Collection of RF Signals Used by Hand-held Devices in Computer Communications," Masters Thesis, Naval Postgraduate School, March 2001.

Lam, W., "Meeting SIGINT Constraints in IP Telephony," Masters Thesis, Naval Postgraduate School, March 2001.

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

KEYWORDS: 802.11, ATM, Wireless, LAN, High Speed Networking, Ad-Hoc Networking

THERMODYNAMIC MODELING FOR INTRUSION DETECTION

John McEachen, Assistant Professor
Department of Electrical and Computer Engineering
James Luscombe, Professor
Department of Physics
Chris Frenzen, Associate Professor
Department of Applied Mathematics
Sponsor: Defense Information Systems Agency

OBJECTIVE: Develop alternative methods for intrusion detection in computer networks. Specifically, examine the use of statistical mechanics in modeling the dynamics of network conversations.

SUMMARY: This interdisciplinary project explored the use of thermodynamic principles to model the flux of conversations across a network boundary. The major deliverable of this project was the Therminator 2 software program developed and installed at the U.S. Pacific Command. A revised version of the software was also installed at the U.S. Army Signal Command, Ft. Huachuca, AZ.

PUBLICATIONS:

McEachen, J.C., Donald, S.D., McMillen, R.V. and Ford, D.K., "Using Thermodynamics to Model Network Conversation Dynamics for Intrusion Detection," *IEEE Transactions in Networking*, in review.

McEachen, J.C., Donald, S.D., McMillen, R.V. and Ford, D.K, "A Thermodynamics-based Model of Network Conversation Flux for Intrusion Detection," to appear in *Proceedings of the IIIS 6th World Multi Conference on Systemics, Cybernetics and Informatics (SCI 2002)*, Orlando, FL, July 2002.

McEachen, J.C., Donald, S.D., McMillen, R.V. and Ford, D.K, "Therminator 2: A Thermodynamics-based Method for Patternless Intrusion Detection," to appear in *Proceedings of the 2002 IEEE Military Communications International Symposium (MILCOM 2000)*, Los Angeles, CA, October 2002.

PRESENTATIONS:

McEachen, J.C., "Therminator 2: A Real Time Thermodynamic-Based Patternless Intrusion Detection System," AFWIC Phoenix Challenge 2002, Las Cruces, NM, 20 February 2002.

THESES DIRECTED:

Donald, S.D. and McMillen, R.V., "Therminator 2: Developing a Real Time Thermodynamic Based Patternless Intrusion Detection System," Masters Thesis, Naval Postgraduate School, September 2001.

Sharlun, G.F., "Defining and Validating a Covert Analysis Detection (CAD) System and its Stealthy Data Capture, Control and Analysis Capabilities," Masters Thesis, Naval Postgraduate School, June 2001.

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

KEYWORDS: Intrusion Detection, Thermodynamics, Statistical Mechanics, High Speed Networking

TIMING CHANNELS IN PACKET NETWORKS

John McEachen, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

OBJECTIVE: Examine the use of packet timing as an alternative communications mechanism. Characterize delay in a variety of network environments.

SUMMARY: This project is based on the work of B. Verdu (1998) in communicating information using inter-packet delay in data networks. This work is largely classified. Work on this project began in February 2002.

PUBLICATIONS:

Miller, B., Copeland, D., Tope, M., Loomis, H. and McEachen, J.C., "An Analysis of Noise in Timing-based Communications over LANs," to appear in *2002 IEEE International Symposium on Circuits and Systems*, Phoenix, AZ, May 2002.

DoD KEY TECHNOLOGY AREA: Command, Control and Communications

KEYWORDS: Packet Networks, Information Theory, Steganography

RADIATION TOLERANT ASIC AND PHOTOVOLTAIC DEVICES FOR SPACE BASED SYSTEMS

Sherif Michael, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To design radiation tolerant mixed mode VLSI and ASIC circuits for space applications. To fabricate these design after extensive simulation using regular silicon process as a first step. To study the Space radiation effects on these state-of-the-art designs using the NPS LINAC as a radiation source. Upon verification of the experimental results, the layout will be submitted for future fabrication using SOI process.

SUMMARY: Continuation of the ongoing research on radiation effects and the design of radiation hardened electronic devices for space applications. The design and fabrication of a high performance digitally programmable VLSI circuit for space-based system. The design is based on a technique that was developed earlier by the investigator, and has shown excellent sensitivity performance. The mixed mode signal circuit, using BiCMOS Techniques is currently under development. Previously fabricated VLSI ASIC chips will also be irradiated using the NPS LINAC for testing its performance under radiation environment. Past experimental results using this technique has shown great improvements in the circuits radiation performance.

PUBLICATIONS:

Michael, S. and Pieper, R., "A VLSI Implementation of a Universal Programmable Low Sensitivity Sampled Data Filter," *IEEE International Symposium on Circuits and Systems*, Vol. 4, pp. 674-677. Sydney, Australia, 6-9 May 2001.

Pieper, R. and Michael, S., "Application of a Robust Algorithm for Predicting Freeze-out and Exhaustion Under a Variety of Nontrivial Conditions," *IEEE International Symposium on Circuits and Systems*, Vol. 2, pp. 477-480, Sydney, Australia, 6-9 May 2001.

THESES DIRECTED:

Fifer, T., "Radiation Effects on Multi-Junction Solar Cells," Masters Thesis, Naval Postgraduate School, December 2001.

Milne, P.R., "The Design, Simulation, and Fabrication of a BiCMOS VLSI Digitally Programmable Filter," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Electronics, Environmental Effects, Other (Space Applications)

KEYWORDS: Space Radiation Effects, Satellites, Annealing, Radiation Hardened, Computer Modeling

GUSTY YEARLING, TASK A

Michael A. Morgan, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: This is a TS level compartmented Special Access Project. No accurate description can be provided for publication in this forum.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Antennas, Propagation, Impulse Radiation

MAGNETIC FIELD SENSOR PLACEMENT AND TIME-REVERSED EM IMAGING STUDIES

Michael A. Morgan, Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVES: This project included two independent investigations, each of which formed the topic of an M.S. Thesis. The first topic sought to optimize near-surface sensor placements to increase the prediction accuracy of magnetostatic near-fields surrounding ferromagnetic objects. Time-reversed wave equation solutions in accoustics were extended to electromagnetics in the second topic, with application to radar imaging.

SUMMARY: Progress for the first topic included: (1) development of a modal algorithm for the field solution due to an axial array of dipoles enclosed within a ferromagnetic spheroidal shell; (2) testing with additive noise of an SVD based least-squares field prediction algorithm using point sensor data, and; (3) extensive searches for optimal sensor placement configurations and the cataloging of findings. Progress for the second topic included development of a finite-difference time-domain simulation and evaluation of imaging accuracy for various levels of noise and sparsity of boundary data.

PRESENTATIONS:

Morgan, M.A. and Steenman, D.G., LT, USN, "Null Spaces for Near-Field Imaging," 2001 URSI National Radio Science Meeting, Boston, MA, 10 July 2001.

Morgan, M.A., Yopp, S.W., LT, USN and Kildishev, A.V., "Optimal Sensor Placement for Magnetic Signature Prediction," 2001 Intermag Symposium, Amsterdam, Netherlands, 2 May 2001.

Kildishev, A.V., Nyenhuis, J.A. and Morgan, M.A., "Multipole Analysis of an Elongated Magnetic Source by a Cylindrical Sensor Array," 2001 InterMag Symposium, Amsterdam, Netherlands, 2 May 2001.

THESES DIRECTED:

Yopp, S.W., "Magnetic Field Estimation Using Optimal Locations of Near Field Sensors," Masters Thesis, Naval Postgraduate School, June 2001.

Inaba, Y., "Radar Target Imaging Using Time-Reversed Processing," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

KEYWORDS: Optimal Sensor Placement, Magnetostatic Field Prediction, Time-Reversed Electromagnetics, Radar Imaging

OPTIMIZED WIDEBAND LOW-PROFILE COMMUNICATION ANTENNA DESIGN

Michael A. Morgan, Professor
Department of Electrical and Computer Engineering
Sponsor: U.S. Army Research Office

OBJECTIVE: Optimal designs of wideband omnidirectional VHF communication antennas will be investigated for rotary-wing and armored vehicle applications.

SUMMARY: Optimization will involve tradeoffs of antenna performance and efficiency constrained by required bandwidth and use of blister type profiles for low aerodynamic drag and mineral surface protrusion. Design will use metallic surface contouring and inhomogeneous dielectric loading under size and shape constraints.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Wideband, Finite Elements, Antenna Design

MODELING AND SIMULATION OF IMPULSIVE RADIATION AND PROPAGATION

Michael A. Morgan, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center

OBJECTIVE: The goal of this task is to investigate the impulse radiation characteristics of specified antennas in the presence of buildings over real earth

SUMMARY: Wire-grid numerical modeling of antenna and building structures has been completed using frequency-stepped calculations using the Numerical Electromagnetics Code (NEC-4). Impulsive near-fields within the modeled building are found using time-domain source modeling and inverse FFT convolution. Animations of fields within the structure are created using custom MatLab programs.

PRESENTATION:

Morgan, M.A., "Impulsive Field Computation and Measurement," 2001 URSI National Radio Science Meeting, Boston, MA, July 10, 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Impulse Response, Antenna Modeling, Near-Fields, NEC

DETERMINING AN OPTIMUM SENSOR NETWORK CONFIGURATION

Phillip E. Pace, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Air Systems Command

OBJECTIVE: This proposal investigates using the Advanced Reactive Electronic Warfare Simulation (ARES) to determine optimum sensor network configurations for applications in electronic attack (EA) and suppression of enemy air defense (SEAD).

SUMMARY: As a first step, appropriate measures of effectiveness (MOEs) were developed in order to define the fitness of a sensor network. For example, a "perfect" sensor network would know everything about the environment with 100% accuracy instantaneously. Appropriate MOEs, therefore, would optimize the sensor network (radars and ESMs) toward perfection (e.g., minimize latency, maximize information content). Working closely with Code 5700 the developed MOEs were embedded into the ARES. The various MOEs were tested to quantify the sensitivity of the solution to (a) the choice of MOE, and (b) the application. From this it was determined if there was an overall best MOE for optimizing the sensor network. The optimized sensor network was applied to several engagement problems (EA and several types of SEAD) in order to determine how well network supported the application.

THESIS DIRECTED:

Pham, P.N., "Sensitivity Analysis of an Optimum Multi-Component Airborne Electronic Attack Configuration for Suppression of Enemy Air Defense," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics, Modeling and Simulation

KEYWORDS: Electronic Attack, Network-Centric Warfare, Optimum Sensor Configuration, Measures of Effectiveness

DIGITAL TARGET IMAGING ARCHITECTURES

Phillip E. Pace, Professor
Douglas J. Fouts, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The technical objective of this research is twofold. The first objective is to quantify the system-level implementation tradeoffs of a digital, programmable imaging architecture to generate realistic false target signatures against high resolution imaging radars, including synthetic aperture radar (SAR) and inverse SAR (ISAR), using all-digital techniques and modern digital radio frequency memory (DRFM) technology. The second objective is to design, fabricate and test an all-digital target imaging device capable of generating large false targets using wideband chirp signals of any duration to provide a new, superior, radio frequency (RF) decoy capability.

SUMMARY: A sequence of simulations was completed to quantify various different design tradeoffs in the high-level architecture of the digital image synthesizer (DIS). The simulations were started during the previous year's effort of this 3-year project. Based on the simulation results, a new, high-performance architecture was developed for the DIS. The design of a high-speed CMOS application-specific integrated circuit (ASIC) that implements the new architecture was then started. The design of this ASIC is now more than half completed, including schematic capture, circuit simulation, mask layout, design rule checking, layout verification, and logic simulation. Simulations indicate the ASIC will function correctly at clock speeds of up to 780 MHz, well beyond the 600 MHz target frequency of the baseband signal. An interface circuit is also being developed to interface the ASIC with a new type of DRFM being developed at the Naval Research Laboratory.

PUBLICATIONS:

Fouts, D.J., Pace, P.E., Karow, C. and Ekestorm, S., "A Single Chip False Target Radar Image Generator for Countering Wideband Imaging Radars," *IEEE Journal of Solid State Circuits* (accepted for publication).

Pace, P.E., Fouts, D.J., Ekestorm, S. and Karow, C., "Digital False Target Image Synthesizer for Countering ISAR," *IEE Proceedings Radar, Sonar and Navigation* (in review).

PRESENTATIONS:

Pace, P.E. and Fouts, D.J., "Digital Target Imaging Architecture for Multiple Large-Target Generation," Office of Naval Research Electronic Warfare Science and Technology Gatherings, Washington, D.C., 9 May 2001.

Pace, P.E., Fouts, D.J., Amundson, C.A. and Guillaume, C., "Digital Target Imaging Architecture for Multiple Large-Target Generation: Critical Design Review," Naval Research Laboratory, Washington, D.C., 6 September 2001.

Fouts, D.J. and Pace, P.E., "Digital Target Imaging Architecture for Multiple Large-Target Generation: Progress Report," Office of Naval Research, Washington, D.C., 19 December 2001.

THESES DIRECTED:

Kirin, K.M., "VLSI Design of Sin/Cos Lookup Table for Use With Digital Image Synthesizer ASIC," Masters Thesis, Naval Postgraduate School, June 2001.

Amundson, C.A., "Design, Implementation, and Testing of a High Performance Summation Adder for Radar Image Synthesis," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics, Computer and Software

KEYWORDS: Imaging Decoys, Inverse Synthetic Aperture Radar, Counter-Targeting, Counter-Terminal, Digital Radio Frequency Memories, DRFM

NAVY SURFACE ANTI-SHIP CRUISE MISSILE THREAT SIMULATOR VALIDATION WORKING GROUP

Phillip E. Pace, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: The objective of this proposal is to provide technical leadership to the Navy Surface Anti-Ship Cruise Missile Threat Simulator Validation Working Group. Three types of simulations are currently being validated by the SVWG for use in test and evaluation. These include (a) radio frequency missile hardware simulators, (b) infrared missile hardware simulators and (c) computer models of missile seekers and related electronics.

SUMMARY: The duties for the SVWG chairman include coordinating with the Navy's Simulator Validation Coordinator, the NRL ENEWS Program Manager and other Navy commands (e.g., Commander Operational Test and Evaluation Force) to prioritize the simulator validations for N912 approval. Additional responsibilities include coordinating with the Office of Naval Intelligence for threat data review and convening the SVWG as an independent and unbiased reviewer for all of the validation reports.

PUBLICATIONS:

Pace, P.E., Zulaica, D., Nash, M.D., DiMattesa, A.D. and Hosmer, A.C., "Relative Targeting Architectures for Captive-Carry HIL Missile Simulator Experiments," *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 37, No. 3, pp. 810-823, July 2001.

Pace, P.E., "Adaptive Power-Managed FMCW Emitter Detection Performance Against Low-RCS Ships," *Proceedings of the IEEE 35th Asilomar Conference on Signals, Systems and Computers, MP8b*, Monterey, CA, 2 November 2001.

PRESENTATION:

Pace, P.E., "Infrared Systems and Analysis," N9 Threat ASCM Simulator Validation Working Group, Naval Research Laboratory, 26 June 2001.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics, Computer and Software

KEYWORDS: Anti-Ship Cruise Missiles, Simulators, Captive-Carry, Hardware-in-the-Loop

OPTIMUM SENSOR NETWORK CONFIGURATION FOR SEAD

Phillip E. Pace, Professor
Department of Electrical and Computer Engineering
Sponsor: Johns Hopkins University, Applied Physics Laboratory

OBJECTIVE: This proposal continues the investigation using the Advanced Reactive Electronic Warfare Simulation (ARES) to determine optimum sensor network configurations for applications in electronic attack (EA) and suppression of enemy air defense (SEAD).

SUMMARY: A sensitivity analysis of the solution evolved by simulation was performed in order to determine the robustness in the derived measures of effectiveness to system failures or variances in the performance parameters. The tasks involved with this effort included simulating the RT-4 distributed scenarios to baseline the corresponding measure of effectiveness (i.e., target engagement time by surface-to-air missile site). One or more parameters in the scenario solution were then changed (receiver dynamic range, jamming assignment, etc.) and the measures of effectiveness were re-derived in order to investigate their sensitivity to these changes. In addition, this project developed a User's Guide for the Naval Research Laboratory (NRL) Advanced Reactive Electronic Warfare Simulation (ARES) software Version 1.12 used in the analysis.

PUBLICATION:

Pace, P.E., Wickersham, D., Jenn, D. and York, N., "High Resolution Phase Sampled Interferometry Using Symmetrical Number Systems," *IEEE Transactions on Antennas and Propagation*, Vol. 49. No. 10, pp. 1411-1423, October 2001.

THESIS DIRECTED:

Pham, P.N., "Sensitivity Analysis of an Optimum Multi-Component Airborne Electronic Attack Configuration for Suppression of Enemy Air Defense," Masters Thesis, Naval Postgraduate School, March 2001. (Classified Secret)

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics, Modeling and Simulation

KEYWORDS: Electronic Attack, Network-Centric Warfare, Optimum Sensor Configuration, Measures of Effectiveness

PHOTONIC ADC ARCHITECTURES FOR MICROWAVE SIGNAL COLLECTION AND ANALYSIS

Phillip E. Pace, Professor
John P. Powers, Distinguished Professor
Department of Electrical and Computer Engineering
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The objective of this proposal is the experimental investigation of a phototonic architecture for high-speef sampling and digitalization of RF and microwave signals.

SUMMARY: The proposed effort consists of three options for funding level (per sponsor request). The photonic ADC used a mode-locked laser to oversample an input signal at two mach-zehnder interferometers. A fiber lattice accumulator is embedded within a feedback loop around a single-bit quantizer to spectrally shape the quantization noise to fall outside the signal band of interest. Decimation filtering is applied to the quantizer output to construct the input signal withhigh resolution. It was proposed to investigate the following: The effects of non-uniform sampling (JITTER), the accumulator leakage resulting from a mismatch in optical circuit parameters, the spurious free dynamic range, signal-to-noise plus distortion ratio AND effective number of bits for several oversampling ratios.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Sensors, Sampling, Electro-Optic, Photonics

REVOLUTION IN BATTLESPACE TECHNOLOGIES WORKSHOP 2001

Phillip E. Pace, Professor
Department of Electrical and Computer Engineering
Sponsor: Swedish National Defense College

OBJECTIVE: This 3-week course hosted by the NPS Center for Joint Services Electronic Warfare, is intended for international military officers and technical research personnel who are interested in the technologies of command and control warfare (C2W).

SUMMARY: The course was sponsored by the Swedish National Defence College (SNDC), and ordered through the Security Assistance Office at the American Embassy in Stockholm under MASL P179220. This year, the workshop was held from April 23 through May 11, 2001. A total of 31 NDC students and eight supporting SNDC staff (including Brigadier General Bjorn Andersson) attended the workshop. All course materials and textbooks were supplied to the students. During the first week there was an Opening Reception and a photo taken of all participants in the course. A field trip to Condor Systems was also taken during the second week. A Flag Dinner and Graduation Ceremony and Dinner were held in week three. Upon completion of the course, students received a Certificate of Graduation. All course materials were mailed back to SNDC upon completion of the course.

PUBLICATION:

Pace, P.C., "Advanced Technical Workshop 2001: Revolutions in Battlespace Technology," Center for Joint Services Electronic Warfare, Volumes I-IV, 23 April–11 May 2001.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics, Modeling and Simulation

KEYWORDS: Workshop, Short Courses, Technology, NPS Center For Joint Services Electronic Warfare

ELECTRONIC WARFARE ADVANCED TECHNOLOGY STUDIES

R. Clark Robertson, Professor
Ron Pieper, Visiting Associate Professor
Department of Electrical and Computer Engineering
Sponsors: Naval Air Warfare Center

OBJECTIVE: The objective of this project was to determine IRCM effectiveness for the F/A-18-E/F for both a smart and a dumb SA threat and a smart AA threat with both straight and level flight as well as maneuvering. In addition, the results obtained with an area source model were to be compared to those obtained with the SPIRITS model.

SUMMARY: The objective of this study was to evaluate MOSAIC based counter-measure predictions for the F/A-18-E/F platform. Various questions were addressed, such as:

1. Do maneuvers when combined with flare drops produce an overall countermeasure improvement for the F/A-18-E/F?
2. Do changes in atmospheric conditions and platform altitude tend to enhance or diminish countermeasure effectiveness?
3. Do the "area" source miss distance results differ significantly with predictions generated using the SPIRITS model? Also, can the percentage of cases in which models disagree as to whether the simulation ends in hit or miss be established?

These questions were addressed for an experimental matrix using various flare salvos, aircraft altitudes, aircraft speeds, and missile types, both surface-to-air and air-to-air. This project is ongoing and will conclude in March 2002.

PRESENTATION:

Robertson, C., "IRCM Effectiveness for the F/A-18-E/F," PMA-272, Patuxent River, MD, October 2001.

THESIS DIRECTED:

Lott, B., "IRCM Effectiveness for the F/A-18-E/F," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY: Electronic Warfare

KEYWORDS: Electronic Countermeasures, IR Countermeasures, IR Sensors

BEARTRAP POST-MISSION ANALYSIS SYSTEM

Murali Tummala, Professor
Charles W. Therrien, Professor
Department of Electrical and Computer Engineering
Sponsor: Advanced Maritime Program Office, Naval Air Station - Patuxent River

OBJECTIVE: To design and develop a signal processing system capable of implementing narrowband frequency tracking, multi-target tracking, wideband and related processing, time-domain analysis, and data fusion for Beartrap post-mission analysis or S2K (for System 2000).

SUMMARY: During 2001, the project was not funded and the activity has been phased out and transferred to the Beartrap site at Brunswick, Maine. The beta testing of the software delivered during 2000 is being carried out at designated sites. The principal investigators are no longer involved in the project.

DoD KEY TECHNOLOGY AREAS: Sensors, Computing and Software, Human Systems Interface, Other (Signal Processing)

KEYWORDS: Signal Processor Design, Acoustic Signal Processing, Graphical User Interface Design

JSIPS-N COMMUNICATIONS ARCHITECTURE MODELING AND SIMULATION

Murali Tummala, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Aviation Depot - Cherry Point

OBJECTIVE: To develop a simulation model for JSIPS-N packet switched communications network, including local and wide area segments and other network components. Issues to be addressed in this effort are performance indicators, assessment of alternate network topologies and system constraints in terms of capacity limitations and maximum number of sites supportable.

SUMMARY: This work produced a baseline model of the Joint Services Image Processing System – Navy Communications system. The model was designed with future expansion in mind, thus it can be used as a design tool and as a means to simulate operational performance prior to making actual design modifications on the network. It can also serve as a management tool to identify areas that require improvement or upgrades. The results illustrate how the baseline model can be used to simulate various operating scenarios. The model was successful in evaluating the overall performance of the system and provided significant data on areas that may require upgrading or configuration improvement.

THESIS DIRECTED:

Hootman, J., "JSIPS-N Baseline Architecture Simulation and Performance Evaluation," Masters Thesis, Naval Postgraduate School, in progress.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

JOINT TACTICAL RADIO SYSTEM (JTRS) AND DIGITAL MODULAR RADIO

Murali Tummala, Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: To develop graduate level course materials for wireless networks with emphasis on software defined radio principles and in support of the digital modular radio program. As part of the work, also investigate the mobile ad hoc routing protocols for use in the DMR program.

SUMMARY: The effort to develop materials for a course on wireless networks and software-defined radio continued during 2001. The routing protocols have been investigated for mobile ad hoc networks: distributed source routing. The effects of the data link, network, and transport level protocols on the quality of real-time data have been studied.

THESIS DIRECTED:

da Silva Mattos, L., "Quality-of-Service Schemes for Mobile Ad-Hoc Networks," Masters Thesis, Naval Postgraduate School, March 2001.

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

KEYWORDS: Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

QUALITY-OF-SERVICE IN MOBILE AD HOC NETWORKS

Murali Tummala, Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: Develop algorithms for quality-of-support assurance in mobile ad hoc networks. Traffic conditioning, marking, and buffer management have been investigated to provide quality of service assurance for real-time traffic in JTRS like environments.

SUMMARY: To achieve QoS, independently of the routing protocol, each mobile node participating in the network must implement traffic conditioning, traffic marking and buffer management or queue scheduling schemes. In MANETs, since the mobile nodes can have simultaneous multiple roles, it was found that traffic conditioning and marking must be implemented in all mobile nodes acting as source nodes. Buffer management and queue scheduling schemes must be performed by all mobile nodes. QoS schemes for different types of traffic, geographical areas of different sizes and various mobility levels have been simulated and their performance studied. Metrics, such as throughput, end-to-end delay and packet loss rates, were used to measure the relative improvements of QoS- enabled traffic sessions. The results indicate that in the presence of congestion, service differentiation can be achieved under different scenarios and for different types of traffic whenever a physical connection between two nodes is realizable.

THESIS DIRECTED:

da Silva Mattos, L., "Quality-of-Service Schemes for Mobile Ad-Hoc Networks," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

RF DISTRIBUTION SYSTEMS AND DMR INTEROPERABILITY

Murali Tummala, Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: To provide research and development support for the digital modular radio procurement program. Issues to be addressed in this effort are integration of distribution systems and interoperability with the digital modular radio system.

SUMMARY: The work consisted of two phases: conducting research to investigate algorithms to provide better traffic management in DMR like environments and interacting with the sponsor and participating in planning and review meetings to assess the interoperability and system procurement. Active queue management mechanisms for real-time traffic for DMR like environments have been developed. A new algorithm called selective early discard (SED) that selectively drops packets in order to spread the packet losses in a queue has been proposed. Using simulation, the new schemes are evaluated in a MANET environment, and their performance is compared with other existing QoS schemes. Results indicate that SED minimizes the burst errors due to buffer overflow, thereby improving the performance for real-time traffic. SED is also capable of providing service differentiation; additional performance improvement can be realized by utilizing timestamps.

THESIS DIRECTED:

Fountanas, L., "Active Queue Management Mechanisms for Real-Time Traffic in MANETs," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Ad Hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

SIGNAL-TO-NOISE ENHANCEMENT PROGRAM

Wilbur R. Vincent, Associate Research Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Security Group

OBJECTIVE: To define factors that adversely affect signal reception at receiving sites, determine the primary characteristics of factors, identify all factors, and provide recommendations for effective mitigation actions.

SUMMARY: Radio noise from overhead power lines has been identified as the major factor limiting the reception of radio signals at 36 of 37 sites examined. This little recognized factor is seriously limiting the effectiveness of HF, VHF, and UHF intercept systems to collect signals of special interest. The primary properties of this noise have been defined, source location procedures have been devised, and a means to identify source hardware has been generated. This effort has generated a number of technical papers and presentations during the last year. Some related work on signal reception in the microwave ISM bands has also been conducted.

PUBLICATIONS:

Parker, A.A., Adler, R.W. and Vincent, W.R., *Conducted EMI from an Engineering Model of DC-to-DC Converter*, Naval Postgraduate School Technical Report, NPS-EC-01-007, June 2001.

Melnick, C., Munsch, G. and Vincent, W., "Signal Reception Survey and Site LZO," prepared for National Security Agency with assistance from Argon Engineering Associates.

PRESENTATIONS:

Vincent, W., Adler, R. and Munsch, G., "A Review of Man-Made Radio Noise at 37 HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Munsch, G. and Adler, R., "A Progress Report on a Model for Man-Made Noise at HF Receiving Sites," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Parker, A., Adler, R. and Vincent, W., "Spectrum Signatures of Man-Made Noise," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Parker, A. and Adler, R., "Ambient Signals and Noise in the 915-MHz ISM Band," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Adler, R. and Munsch, G., "Operation of a 2.4 GHz Portable Phone with Noise from a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

Vincent, W., Adler, R. and Munsch, G., "The Temporal and Spectral Properties of Radio Noise from a Microwave Oven," Conference on Factors Affecting the Reception of Radio Signals, Naval Postgraduate School, 5-6 March 2001.

OTHER:

Parker, A., Adler, R. and Vincent, W., "Parasitic Oscillations from an Active Television Antenna," prepared in cooperation with the Department of Oceanography, Naval Post Graduate School.

Vincent, W. and Munsch, G., "Power-Line Noise Mitigation Handbook for Naval and Other Receiving Sites," draft of 5th edition. (This handbook was extensively updated during the 2001 and it will be published in early 2002.)

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Radio Noise, Interference, Spectrum Signatures

FIRST PRINCIPLES PREDICTION OF X-RAY IMPULSE

Donald van Z. Wadsworth, Senior Lecturer
Department of Electrical and Computer Engineering and Space Systems Academic Group
Sponsor: Navy Strategic Systems Programs Office

OBJECTIVE: The multi-year objectives are: (i) collect and archive key data (reports and interviews) relevant to predicting the vulnerability of an RB aeroshell to an x-ray burst in space, (ii) compare the capability of existing physics-based models (finite-element hydrocodes and radiation deposition codes) to predict blow-off impulse and damage to various RB composite materials, (iii) modify a selected code to improve fidelity, (iv) validate the modified code against existing test data (UGT and AGT) and, if needed, plan and execute new tests using existing facilities (flash x-ray and surface loading), (v) establish a continuing core effort at NPS in support of SSP, involving faculty, graduate students, and coordination with related efforts at the DoE National Laboratories, DTRA, NNSA, NRL, and AFRL.

SUMMARY: Field trips to SSP headquarters, DTRIAC, and the National Laboratories (LANL, SNL, LLNL) resulted in a mine of documents covering the extensive restricted work in this field during the past 30 years. This together with extensive discussions with the experts at the various laboratories provided an ideal starting point for this project. With the support of key personnel at LLNL, as well as a Navy Master's Degree Thesis student and Professor Don Danielson (NPS Applied Mathematics Deptartment), a weapons code was utilized to evaluate the shock impulse to a representative aeroshell due to a standard nuclear ABM threat model. Professor Knox Milsaps, Mechanical Engineering Deptartment, is the co-advisor for the thesis.

After significant difficulty due to the different security organizations in DoE and DoD, DoE clearances were obtained for all involved and a classified mail channel was opened between LLNL and NPS, which is proving invaluable in pursuing this research project.

Installation at NPS of the SNL finite element hydrocode, CTH, was begun and will be evaluated during CY2002. Professor Danielson examined the commercial hydrocode, DYTRAN, for use in this project. Both CTH and DYTRAN will require addition of a radiation deposition module. A start was made in determining the suitability of using the NPS electron-beam machine for validating selected modeling code predictions. SNL colleagues suggested using their Z-pinch machine as a flash x-ray source for radiating aeroshell samples which were obtained from the SSP contractor.

DoD KEY TECHNOLOGY AREA: Other (Nuclear Weapons Effects, Hydrocodes)

KEYWORDS: Nuclear Weapons, X-Ray Radiation, Thermomechanics

SILVACO TOOLS DEVELOPMENT FOR RADIATION EFFECTS

Todd Weatherford, Assistant Professor
Andrew Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsors: Naval Surface Warfare Center – Crane Division

OBJECTIVE: To develop semiconductor simulation tools to improve modeling of radiation effects in semiconductor devices.

SUMMARY: Work in 2001 has continued on modeling radiation effects in Metal-Oxide-Semiconductor Silicon-on-Insulator (SOI) structures and charge trapping in buried oxides. The SOI modeling has been expanded to examine radiation effects on sense amps and analog circuitry for ferroelectric memories. Additional duties to test, model and design radiation hardened InGaAs photodetectors for InteFermetric Optical Guidance (IFOG) systems. A third project included in this research included the addition of characterizing ferroelectric capacitors.

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

KEYWORDS: Electronics, Materials, Processes and Structures, Modeling and Simulation, Silicon-on-Insulator

SUPPORT FOR THE NPS LINEAR ACCELERATOR (LINAC)

Todd Weatherford, Assistant Professor
Andrew Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsors: Various Activities

OBJECTIVE: Provide operation of the NPS LINAC and Flash X-ray facilities to internal and external users to study radiation effects in semiconductors and other materials.

SUMMARY: In 2001 both facilities have been maintained and improved for dosimetry. Over eight outside firms and three NPS researchers have utilized the facilities in CY01. The facilities have supported reimbursable research, which include student master theses.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Electronics

KEYWORDS: Radiation Effects, Electronics, Particle Accelerators, Materials, Semiconductors

AEA ARCHITECTURE AND PLATFORM MIXES

Lonnie A. Wilson, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Air Systems Command

OBJECTIVE: The objective is to perform top level analysis of AEA (Advanced Electronic Attack) Architecture and Platform Mixes and identify key capabilities and needs to support the OSD AEA EA-6B follow-on studies.

SUMMARY: The EA-6B service life is through 2015–2020 requiring a follow-on platform or platform mix to the ICAP III upgrade expected to IOC in 2004. These efforts used the EA-6B ICAP III as a baseline to build a future Electronic Attack (EA) capability to accomplish the SEAD role and other Information Operation missions. This core tactical capability includes radar jamming, communication jamming, hard-kill capabilities, and connectivity to ISR and offboard assets. The expected results were a platform mix utilizing available technology to develop a system of systems to provide future EA capabilities.

AEA candidate air vehicles are manned or unmanned, performing either the dedicated AEA role or having AEA capability as part of their multi-mission capability. The nature of AEA support requires detailed knowledge of the supported air, ground and sea forces and emerging warfighter concepts in Information Operations (IO).

The fundamental goal of the AEA was to find the most mission capable, cost effective solution to tactical aviation requirements for electronic warfare (EW) support. The initial requirement is driven by the necessity to replace an aging EA-6B airframe.

The architecture and preliminary design were completed for a digital ES (Electronic Support) receiver and processor for the AEA application. Technical performance improvements and new operational performance capabilities were identified. The AEA Technical Working Group agreed to develop the digital EC receiver along with high performance DSP with Specific Emitter Identification. NPS participated and supported the AEA Technical Working Group, the Digital Receiver Focus Group and the SEI Focus Group.

A new digital match filter concept was developed and demonstrated for the high performance detection and processing of LPI radar signals.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Other (Radar, Strike, and Surveillance)

KEYWORDS: EW, EA, Architecture, F-18G, UAV, UCAV, and IW

ELECTROMAGNETIC SUSCEPTIBILITY AND ANALYSIS OF CRITICAL INFRASTRUCTURE SYSTEMS

Lonnie A. Wilson, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: The basic objective is to research the electromagnetic susceptibility of critical infrastructure systems.

SUMMARY: The research started the electromagnetic susceptibility and analysis of critical infrastructure systems. This initial research included the EM susceptibility and analysis for one infrastructure system.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Other (Information Warfare)

KEYWORDS: Electromagnetic, Radar, Electronic Warfare, IW

HIGH PERFORMANCE ELINT DEINTERLEAVER DEVELOPMENT

Lonnie A. Wilson, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: The basic objective is to develop a High Performance ELINT Deinterleaver (with contamination screening and deinterleaving processing) using classical and intrapulse parameters. This development builds on previous efforts including key technical feasibility demonstrations for High Performance ELINT SEI Processor.

SUMMARY: The NPS Deinterleaver is conceptually divided into two parts: 1) Preprocessor Section and 2) Deinterleaver Processor. Inputs to the deinterleaver include digitized IF from either pre-recorded standard data sets or operational feeds. Also, the Deinterleaver accepts optional AOA and TOA data.

Deinterleaver outputs include sorted Pulse Word Trains or Pulse Bursts to the SEI association algorithms. Also, deinterleaver pulse numbers and pulse parameter sets are passed to the IF Pulse Data Distribution for recording purposes, if desired.

From a single pulse, parameter estimates include: frequency, TOA, AOA, pulsewidth, risetime, amplitude modulation on pulse, phase modulation on pulse, frequency modulation on pulse, peak

amplitude, pulse peak power, noise power, SNR. Also, interpulse parameters are derived from single pulse parameter information. Interpulse parameters include PRF, Scan and other parameters.

The Preprocessor Section includes: Digital Pulse Detection, Pulse Saturation and Minimum SNR Screen, Average Carrier Frequency Tune Error and Gross Interference Screen. The Deinterleaver Processor includes classical and MOP (intrapulse signals) Parameter Extractions, and Deinterleave Unit.

The Deinterleaver algorithms include classical and Modulation on Pulse (MOP) parameter extractions in the optimal characterization bandwidth, assignment of confidence to all measured parametrics, and a data formatting process. Angle of Arrival (AOA) centroiding and multi-channel complex voltage conjugates (phase & amplitude) will only be done in future development tasks. The NPS implementation has a single channel capable of batch processing output records to associate pulse descriptor words into bursts and trains using MOP parametrics and classical parameters, with confidence factors.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Sorting, ID, RF Receiver, MOP Signal Extraction, Parameter Extraction, Targeting

NPS STUDENT AND FACULTY HIGH POWER MICROWAVE (HPM) RESEARCH

Lonnie A. Wilson, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: The basic objective of this research is to continue development of high power microwave (HPM) and ultra-wideband (UWB) technology and capabilities research at the Naval Postgraduate School including source and systems engineering and design, modeling and simulation and effects testing. This work will have application to ship defense, information warfare/information operations (IW/IO), and human-computer interface (HCI).

SUMMARY: Critical Infrastructure Protection (CIP) developments were performed using basic technology analysis and fundamental signal processing considerations for one infrastructure system. The NPS research used multiple signals from a specific electronic environment. SPY-1 radar and other radars were considered in the selected receiver system and processing results were analyzed.

DoD KEY TECHNOLOGY AREA: Human Systems Interface, Modeling and Simulation

KEYWORDS: HPM Source, Systems, Wideband, IW, IO

MOTION TRACKING USING INERTIAL SENSORS

Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Chief of Naval Operations (N6M) and Army Research Office

OBJECTIVE: To develop a hybrid inertial/magnetic body tracking system for use in a networked virtual environment.

SUMMARY: An improved Magnetic, Angular Rate, Gravity (MARG) Body Tracking System was designed and implemented. The current MARG Body Tracking System is limited to tracking three limb-segments. The MARG sensors are physically connected to a desktop computer by cables. In this year, a multiplexing circuit was implemented to allow tracking of 15 limb-segments. Processing was moved from a desktop computer to a wearable computer and wireless communication was implemented using an IEEE 802.11b spread spectrum wireless LAN. The resultant system is able to track the entire human body and is untethered. The range of the system is the same as that of the wireless LAN which can be extended with the use of repeaters.

The second effort of this project was to develop a realistic human avatar to be interfaced with the MARG sensor system. With the continuing gain in computing power, bandwidth, and Internet popularity

there is a growing interest in Internet communities. To participate in these communities, people need virtual representations of their bodies, called avatars. Creation and rendering of realistic personalized avatars for use as virtual body representations is often too complex for real-time applications such as networked virtual environments (VE). Virtual Environment (VE) designers have had to settle for unbelievable, simplistic avatars and constrain avatar motion to a few discrete positions. The approach taken in this project is to use a full-body laser-scanning process to capture human body surface anatomical information accurate to the scale of millimeters. Using this 3D data, virtual representations of the original human model can be simplified, constructed and placed in a networked virtual environment. The result of this project is to provide photo realistic avatars that are efficiently rendered in real-time networked virtual environments. The avatar is built in the Virtual Reality Modeling Language (VRML). Avatar motion can be controlled either with scripted behaviors using the H-Anim specification or real-time data from the MARG sensors. Live 3D visualization of animated humanoids is viewed in freely available web browsers.

PUBLICATIONS:

Marins, J.L., Yun, X., Bachmann, E.R., McGhee, R.B. and Zyda, M.J., "An Extended Kalman Filter for Quaternion-Based Orientation Estimation Using MARG Sensors," *Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 2003-2011, Maui, HI, 29 October-3 November 2001.

Bachmann, E.R., McGhee, R.G., Yun, X. and Zyda, M.J., "Inertial and Magnetic Posture Tracking for Inserting Humans into Networked Virtual Environments," *ACM Symposium on Virtual Reality Software and Technology (VRST'01) Proceedings*, pp. 9-16, Banff, Alberta, Canada, 15-17 November 2001.

THESES DIRECTED:

Hollis, P.G., "An Improved Magnetic, Angular Rate, Gravity (MARG) Body Tracking System," Masters Thesis, Naval Postgraduate School, June 2001.

Dutton, J.A., "Developing Articulated Human Models from Laser Scan Data for Use as Avatar in Real-time Networked Virtual Environments," Masters Thesis, Naval Postgraduate School, September 2001.

Aljuaied, A.M., "Bluetooth Technology and Its Implementation in Sensing Devices," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Motion Tracking, Inertial Sensors, Human Avatar, Wireless LAN

REDUCED CREW SIZE METROLOGY USING WIRELESS LANs AND WEARABLE PCs

Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center

OBJECTIVE: To investigate the Reduced Crew Size (RCS) Metrology using WLANs and wearable computers.

SUMMARY: Working with the Measurement Science Directorate (MSD) of the Naval Surface Warfare Center (NSWC-Corona), feasibility of developing a general purpose calibration system using wearable computers and wireless LANs was studied. In particular, a prototype of pressure calibration system has been developed. The system includes a software module that makes it possible to submit calibration data to a remote server using wired or wireless LAN. The prototype system was demonstrated at the Fleet Maintenance Symposium at San Diego on 27-29 August 2001.

THESIS DIRECTED:

Ly, T.T., "Shipboard Wireless Network Applications," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Metrology, Wireless LAN, Wearable Computer

SUBMARINE WIRELESS LOCAL AREA NETWORKING

Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: To test and evaluate IEEE 802.11b compliant wireless LAN product components with respect to EMI/EMC for submarine damage control communications.

SUMMARY: A preliminary EMC study of COTS wireless LAN components was conducted. The difference between FCC Part 15 requirements and MIL-STD-461E requirements was investigated. It was noted that FCC Part 15 restrictions for radiated emissions are more stringent in the frequency ranges of 2.4 GHz and higher as compared to MIL-STD-461E. It was also noted that FCC Part 15 lacks sufficient requirements for susceptibility. Four tests of MIL-STD-461E (CE102, RE102, CS101, RS103) were conducted on the Aironet 4800 DS wireless LAN components. These four tests represent one in each of the required testing areas: conducted emissions, radiated emissions, conducted susceptibility, and radiated susceptibility. Based on these limited tests, it appears that the Aironet 4800 series of wireless LAN components are electromagnetically compatible with the submarine systems.

A Java based application for Damage Control (DC) communications was developed. The application uses multicast sockets to send standard DC and crew reports from handheld devices to the DCC console (see figure below) wirelessly.

OPNET Modeler 7.0B was used to produce a simulation of the proposed Virginia Class wired/wireless network, in the presence of a type load. The creation of a detailed 24-hour workload includes various combinations of HTTP, FTP, EMAIL, DB and Audio and Video to accomplish their tasks. This full workload was then applied to the built OPNET simulation. Subnet-to-Subnet throughput and application response time graphs show that the designed network would work well. Sensitivity analysis was also performed to determine when this system would fail by progressively increasing the full workload factor. This analysis showed that the system performs satisfactorily up to 152 wireless clients (each carrying a full workload). To provide an extra layer of validity to the simulation, an analytical model was developed for the longest path scenario and the Ethernet delay was compared. The results showed the simulation to be accurate based on similar Ethernet delays.

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Peck, E.A., "Analysis and Evaluation of the Electromagnetic Compatibility of COTS Wireless LAN Components Onboard Submarines," Masters Thesis, Naval Postgraduate School, September 2001.

Wilkins Jr., W.G., "Concepts, Applications and Analysis of a Submarine Based Wireless Network," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Command, Control and Communication

KEYWORDS: Damage Control, Wireless Computer Networks

COMPUTER AIDED DETECTION FOR THE SYNTHETIC APERTURE SONAR SYSTEM

Lawrence J. Ziomek, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: Derive accurate equations that will allow one to compute the probability of detecting a mine-like- object (MLO) for a given probability of false alarm (false-alarm rate) for a given ocean environment. Work will begin on deriving an expression for the signal-to-interference power ratio (SIR) at the output of a correlator receiver that will take into account the propagation in the ocean medium of an acoustic signal from the transmit array to the target, and from the target back to the receive array. The probability of detection can be related to both the probability of false alarm and the SIR. Efforts will be made to express the SIR in terms of the complex scattering amplitude functions of different types of mines and ocean bottoms, and in terms of "target" and "reverberation" ambiguity functions.

SUMMARY: A set of pulse-propagation coupling equations was successfully derived. They couple the output electrical signal at a point element in a receive array to the transmitted electrical signal at the input to a transmit array via the complex frequency response of a fluid medium (e.g., air or water). The pulse-propagation coupling equations are based on linear, time-variant, space-variant, filter theory, the principles of complex aperture theory and array theory, and solving a linear wave equation, which includes satisfying all boundary conditions, including the boundary condition at the source. The time-variant, space-variant, complex frequency response of the ocean was shown to be the time-harmonic solution of a linear wave equation when the source distribution is a time-harmonic point source.

The pulse-propagation coupling equations provide a consistent, logical, and straightforward mathematical framework that can be used to accurately model the propagation of small-amplitude acoustic pulses in the ocean for a bistatic scattering problem. The main features of the pulse-propagation coupling equations are as follows: 1) transmitted electrical signals are modeled as amplitude-and-angle-modulated carriers, 2) both the transmit and receive apertures are modeled as volume, conformal arrays composed of unevenly-spaced, complex-weighted, point elements (this type of model for both of the apertures allows for maximum flexibility), 3) the complex weights are frequency dependent and allow for beamforming, 4) the performance of the point elements in both the transmit and receive arrays are characterized by frequency-dependent, transmitter and receiver sensitivity functions, and 5) the solution of a linear wave equation is given by the complex frequency response of the fluid medium. It is important to note that attention to all proper units of measurement were taken into account in order to ensure the accurate prediction of signal strength levels at each element in a receive array. This is especially important, for example, in order to obtain accurate probability of detection results.

Derivations of the complex frequency response of the ocean for the following three different bistatic scattering problems were performed: 1) no motion, 2) only the discrete point scatterer is in motion, and 3) all three platforms (the transmitter, discrete point scatterer, and receiver) are in motion. Specific examples on the use of the pulse-propagation coupling equations were given for the three different bistatic scattering problems. Scatter from a discrete point scatterer was modeled via the scattering amplitude function, which is a complex function (magnitude and phase) and is, in general, a function of frequency, the direction of wave propagation from the source to the scatterer, and the direction of wave propagation from the scatterer to the receiver. In addition to the scattering amplitude function, frequency-dependent attenuation was taken into account in order to model the propagation of sound from transmitter to discrete point scatterer, and from discrete point scatterer to receiver. The dimensionless, time-compression/time-stretch factor was derived and discussed for the two bistatic scattering problems involving motion. The time-compression/time-stretch factor takes into account the relativistic effects of motion and provides for accurate time delay and Doppler shift values.

PUBLICATION:

Ziomek, L.J., *Pulse Propagation and Bistatic Scattering*, Naval Postgraduate School Technical Report, NPS-EC-02-001, 26 October 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Detecting Mine-Like Objects, Signal-to-Interference Power Ratio, Target Ambiguity Functions, Reverberation Ambiguity Functions

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

2001
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OTHER

McEachen, J.C., *Therminator 2*: This next-generation thermodynamics-based intrusion detection system has been installed at the Pacific Command (PACOM) Network Operations Center (NOC) and the Army Signal Command Ft. Huachuca NOC. It is being evaluated for general release to the public by SANS.

McEachen, J.C., *IEEE 802.11a Standard Baseline and Rate Agility Computer Simulation Models*: This is a baseline software model of the new IEEE 802.11a protocol developed using the OPNET simulation tool. 802.11a represents the next generation of high-speed wireless local area networks (WLAN). The first 802.11a product was released in August 2001. The model includes both the medium access control (MAC) and physical (PHY) layers of the standard. Two data rate agility mechanisms may also be analyzed using the model. Available publicly at the OPNET™ Contributed Models Depot (ftp://opguest:opguest@corporate7.opnet.com/310/).

McEachen, J.C., *Fibre Channel Computer Simulation Model*: These OPNET™ models are the basic components of a Fibre Channel system. Specifically, a channel node, a switch, and the fibre channel frame format are modeled and simple simulations are included. Available publicly at the OPNET™ Contributed Models Depot (ftp://opguest:opguest@corporate7.opnet.com/311/).

McEachen, J.C., Online.ECE WWW Course Portal: Established a consolidated course portal for EC web-based learning initiatives sponsored by COMSPAWARSYSCOM. This course provided a focal point for electronic course materials developed within the EC department.

McEachen, J.C., NSA Distance Learning Remote Computer Facility: Installed and configured a system for Distance Learning students at the NSA to run EC computer assignments (MATLAB and OPNET) from their remote workcenter desktop by leveraging off research facilities locally. Facility included a WWW site for dissemination of class assignments, instructions, lecture notes, and software.

McEachen, J.C., EC4960 Course Materials WWW Server: (A resource containing complete collection of lecture notes, computer assignments, homework solutions, test keys, and software help manuals used to facilitate the instruction of EC4800. (http://web.nps.navy.mil/~mceachen/ec4800/):

McEachen, J.C., EC3850 Course Materials WWW Server: A resource containing complete collection of lecture notes, computer assignments, homework solutions, test keys, and software help manuals used to facilitate the instruction of EC3850. (http://web.nps.navy.mil/~mceachen/ec3850/)

McEachen, J.C., EO3513 Course Materials WWW Server: A resource containing complete collection of lecture notes, computer assignments, MATLAB code, frequently asked questions, homework solutions, test keys, and software help manuals used to facilitate the instruction of EO3513. (http://web.nps.navy.mil/~mceachen/eo3513/)

McEachen, J.C., EC2010 Course Materials WWW Server: A resource containing lecture notes, computer assignments, homework solutions, and test keys used to facilitate the instruction of EC2010. (http://web.nps.navy.mil/~mceachen/ec2010/)

DEPARTMENT OF APPLIED MATHEMATICS

MICHAEL MORGAN
CHAIR

APPLIED MATHEMATICS

OVERVIEW:

The NPS Applied Mathematics Department is committed to excellence. Our purpose is to provide an exceptional mathematical education focused on the unique needs of our students, to produce relevant research for our sponsors, and to provide quality service to the community. We further are committed to maintenance of a well-designed curriculum and a supportive environment for our students.

CURRICULA SUPPORTED:

- The majority of the departmental effort is devoted to the service courses offered which support a variety of curricula.

DEGREES GRANTED:

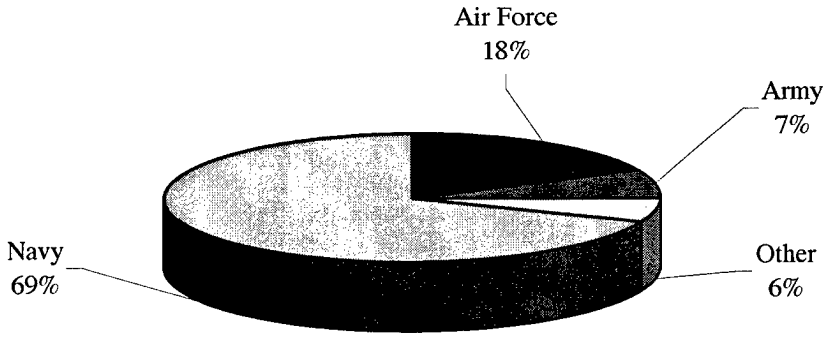
- Master of Science in Applied Mathematics
- Doctor of Philosophy

RESEARCH THRUSTS:

- Scientific Computation
- Control Theory
- Approximation
- Numerical Modeling

RESEARCH PROGRAM (Research and Academic)-FY2001:

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



Size of Program: **$271K**

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TOTAL LEAST SQUARES FITTING OF ORDERED DATA WITH POLYNOMIAL SPLINES

Carlos F. Borges, Associate Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: To develop fast and numerically stable algorithms for fitting polynomial splines to ordered data with minimal error in the total least-squares sense.

SUMMARY: This unfunded effort is a continuing research project. The idea is to fit parametric polynomial spline curves to ordered data to get the best possible fit. Unlike traditional least-squares methods we assume that errors may occur in both the x and y directions. Moreover, we allow the data to be completely general - in particular, it does not have to be functional in nature, it may overlap itself or change directions without restriction. All that is required is an ordered set of points in the plane. A variety of different approaches have been investigated and some very fast and robust algorithms have been developed for solving the problem for a single Bezier curve. These algorithms have been extended to work with B-spline curves with general knot sequences. This past year a paper was submitted on this work to Computer Aided Geometric Design. The paper has been accepted and should appear in 2002.

PUBLICATIONS:

Borges, C.F. and Pastva, T.A., "Total Least Squares Fitting of Bézier and B-Spline Curves to Ordered Data," *Computer Aided Geometric Design*, Vol. 19, No. 4, pp. 275-289, 2002.

DoD KEY TECHNOLOGY AREA: Other (Scientific Computation)

KEYWORDS: Curve Fitting, Data Compression, Approximation Theory

RESEARCH IN THE STRUCTURAL DYMAMIC RESPONSE OF THE RAH-66 COMMANCHE HELICOPTER

Donald A. Danielson, Professor
Department of Applied Mathematics
Sponsors: Comanche Program Office and Naval Postgraduate School

OBJECTIVE: Professor Danielson continued his work in support of ongoing development of the Army's RAH-66 *Comanche* helicopter. Two NPS thesis students supported him. This year he used a finite element code to predict the effects of an explosion inside the forward tailcone of the Comanche.

SUMMARY: The model was based on Comanche structural information from engineers Jason Firko and Mel Niederer, located at Boeing helicopters in Philadelphia. The MSC.Software code Patran was used as the pre and post processor, and the MSC.Software code Dytran as the computational engine. The Catia model was not suitable for meshing, but the geometry therein was transferred to a new group and became the basis for the model. With further study of copies of the large engineering drawings, a faithful replica of the Comanche tailcone was constructed. The final geometry consists of 56 surfaces and 10 solids. The tailcone structure is meshed with 25,261 Lagrangian elements (16,665 2-D shell elements plus 8,596 3-D solid elements) of edge length 1 inch. The fluid region is meshed with 22,113 3-D solid Eulerian elements of edge length 2 inches. The model has 5 different 2-D orthotropic materials, which are used to construct the laminate composites for the shell elements. It also uses an aluminum material for some shell elements. The vents' shell elements are modeled with an extremely weak material, so that the inner surface forms a closed volume (required in Dytran). A 3-D orthotropic material is assigned to the solid Lagrangian elements. Material properties of air are assigned to the Eulerian elements. Generic (unclassified) initial properties are used for the sphere containing the blast wave. A job was run and graphical results were inserted into the final report.

PUBLICATIONS:

Danielson, D. A., "Comanche Tailcone Model Documentation," Naval Postgraduate School Report, sent to Boeing, 2001.

THESIS DIRECTED:

Gorak, M. and Libby, J., "Finite Element Modeling of the RAH-66 Comanche Tailcone Section Using Patran and Dytran," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Helicopters, Airframes, Explosions, Computer Software

EFFICIENT TRAJECTORY OPTIMIZATION

Fariba Fahroo, Associate Professor
Department of Applied Mathematics
Sponsor: Draper Labs

OBJECTIVE: The objectives of this research are to explore spectral patching techniques, their accuracy, and efficiency for solving both continuous and discontinuous trajectory optimization problems.

SUMMARY: This research produced a numerical method for solving complex trajectory optimization problems in a rapid manner. The spectral patching method developed advances the state of the art in trajectory optimization by providing solutions that are provably optimal. In this project, the spectral patching method was developed and implemented in MATLAB. A numerical package called DIDO, which was based on the numerical method was developed and a launch problem among other examples from astronautics were solved using the package.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Space Vehicles, Modeling and Simulation

KEYWORDS: Spectral Patching Techniques, Trajectory Optimization

DEPLETION LENGTHS IN SEMICONDUCTOR NANOSTRUCTURES

Chris Frenzen, Associate Professor
Department of Applied Mathematics
James Luscombe, Professor
Department of Physics
Sponsor: Unfunded

OBJECTIVE: In this research a formula for the depletion length in a cylindrical nanostructure was developed, and investigated in various asymptotic limits. It was shown that the standard formula for depletion lengths at a planar semiconductor interface underestimates the depletion length in nanostructures of finite radius.

SUMMARY: The depletion, W(R), at the surface of a cylindrical nanostructure of radius R is calculated and shown to satisfy a certain inequality which bounds W(R) below by W_p and above by W_p times the square root of two, where W_(p) is the depletion length at a planar interface. The standard result W_p is shown to underestimate the depletion length in a finite structure. The discrepancy between W_p and W(R) becomes significant when the dimensions of the structure become comparable to the depletion length, as can occur in nanostructure devices. This work has been accepted for publication in the journal *Solid State* and will appear in 2002.

PUBLICATIONS:

Frenzen, C., "Depletion Lengths in Semiconductor Nanostructures," *Solid State Electronics*, Vol. 46, pp. 885-889, 2002.

DoD KEY TECHNOLOGY AREAS: Manufacturing Science and Technology (MS&T)

KEYWORDS: Semiconductor Nanostructures, Depletion Length

EFFICIENT NONLINEAR TRANSIENT DYNAMIC ANALYSIS FOR STRUCTURAL OPTIMIZATION USING AN EXACT INTEGRAL EQUATION FORMULATION

Joshua Gordis, Associate Professor
Department of Mechanical Engineering
Beny Neta, Professor
Department of Applied Mathematics
Sponsor: National Science Foundation

OBJECTIVE: The focus of this phase of the project is the development of an improved solution algorithm for fast transient analysis of large, locally nonlinear structures using time domain structural synthesis.

SUMMARY: Time domain structural synthesis is a general and exact formulation for transient problems in structural modification, substructure coupling, and base excitation. The formulation is characterized by the governing equation of the synthesis, which is a nonlinear Volterra integral equation. The governing equation makes use of impulse response functions calculated for those coordinates of the (sub) structures subjected to forces of synthesis (e.g. modification forces, coupling forces). This physical coordinate formulation provides for a largely unrestricted and exact model reduction, in that only those coordinates of interest need be retained in the synthesis. The development of several algorithms intended to improve upon the original algorithm developed by Gordis are documented.

The last algorithm developed meets the stated goals of the project. This algorithm is a newly developed recursive, block-by-block convolution solution to the governing nonlinear integral equation. As is demonstrated with a simple but realistically large nonlinear base excitation problem (51,500 DOF finite element model), the new algorithm provides a 78% reduction in time required for the nonlinear transient base excitation solution, as compared with traditional direct integration calculated using a widely-used commercial finite element program. This very large savings in computer time is obtained for a single analysis, i.e. assuming no prior calculations have been made for the impulse response functions of the (sub) structures. The new algorithm provides an even greater reduction in computer time for all subsequent analyses. As shown in the example problem, once all required impulse response functions have been calculated, the nonlinear base isolation solutions calculated using the new recursive, block-by-block convolution algorithm take approximately 7 seconds, as compared with the direct integration solution, which takes approximately 30 minutes. This rapid reanalysis capability will facilitate the development of numerical optimization for the design of nonlinear isolation.

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

KEYWORDS: Finite Elements, Structural Synthesis, Convolution, Block-By-Block, Adaptive

COORDINATED FORMATION AND ATTITUDE CONTROL OF MULTI-SATELLITE SYSTEMS

Wei Kang, Associate Professor
Department of Applied Mathematics
Sponsor: Air Force Research Laboratory and Naval Postgraduate School

OBJECTIVE: The objectives of the project are (1) design robust feedbacks that meet the needs of attitude control and coordination; (2) identify some attitude stabilization and attitude tracking problems that is useful for satellite formation missions; (3) selection of key parameters to build a perceptive frame; (4) reference projection design, and hybrid control architecture design for the purpose of coordinated control; (5) simulation and lab test of the control design.

SUMMARY: The PI visited AFRL on WPAFB three times to collaborate with the AFRL research team in this subject. The design algorithm based on perceptive frame developed in NPS and MSU is combined with an H-infinity optimal attitude controller to coordinate multiple satellites. Two conference papers and a journal paper from this project were published or accepted during October 2000-September 2001. One more journal paper was submitted.

PUBLICATIONS:

Kang, W., Xi, N. and Sparks, A., "Theory and Applications of Formation Control in a Perceptive Referenced Frame," *Proceedings IEEE Conference on Decision and Control*, Sydney, Australia, 12-15 December 2000.

Kang, W., Yeh, H.H. and Sparks, A., "Coordinated Control of Relative Attitude for Satellite Formation," *Proceedings AIAA Guidence, Navigation, and Control Conference*, 6-9 August 2001.

Kang, W. and Yeh, H.H., "Coordinated Attitude Control of Multi-Satellite Systems," *International Journal of Robust and Nonlinear Control*, Vol. 12, pp. 185-205, 2002.

Nelson, E., Sparks, A. and Kang, W., "Coordinated Nonlinear Tracking Control for Satellite Formations," *Proceedings AIAA Guidence, Navigation, and Control Conference*, 6-9 August 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Space Vehicles, Modeling and Simulation

KEYWORDS: Attitude Control

VISIBLE SETS AND ITS MANUFACTURING APPLICATIONS

Wei Kang, Associate Professor
Department of Applied Mathematics
Sponsor: Ford Scientific Research Lab and Naval Postgraduate School

OBJECTIVE: The focus of this project for the year of 2001 is on the production planning based on information feedback. Mathematical model of production planning integrating both statistical data and IT based fast information feedback is developed.

SUMMARY: An index theory was developed for the proposed problem. It numerically interprets the visibility of each side of a mechanical part. Dynamical programming is applied with the index theory to minimize the number of sensor locations to inspect every surface of a mechanical part. Also funded by Ford Scientific Lab, the Robotics Lab of MSU is building up a system with robot arms, sensors and softwares. The theory developed in this project will be implemented in the lab, and the entire system will be tested using real auto parts from the sponsor.

PUBLICATIONS:

Kang, W. and Song, M., "Manufacturing Planning Based on Information Feedback," *Proceedings 6th International Conference on Control, Automation, Robotics and Vision,* Singapore, 5-8 December 2000. (Best Paper Award, 6th International Conference on Control, Automation, Robotics and Vision, Singapore, 5-8 December 2000.)

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manufacturing Science and Technology (MS&T)

KEYWORDS: Production Planning

GALERKIN SPECTRAL SYNTHESIS METHODS

Beny Neta, Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: To develop existence and uniqueness theory for the energy dependent, steady state neutron diffusion equation with inhomogeneous oblique boundary conditions imposed. Also to develop a convergence theory for the Galerkin Spectral Synthesis Approximations.

SUMMARY: An existence and uniqueness theory is developed for the energy dependent, steady state neutron diffusion equation with inhomogeneous oblique boundary conditions imposed. Also, a convergence theory is developed for the Galerkin Spectral Synthesis Approximations which arise when trial functions depending only on energy are utilized. The diffusion coefficient, the total and scattering cross-sectional data are all assumed to be both spatially and energy dependent. Interior interfaces defined by spatial discontinuities in the cross-section data are assumed present. Our estimates are in a Sobolev-type norm, and our results show that the spectral synthesis approximations are optimal in the sense of being of the same order as the error generated by the best approximation to the actual solution from the subspace to which the spectral synthesis approximations belong.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Galerkin, Spectral Synthesis, Diffusion

ORBIT DETERMINATION

Beny Neta, Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: To develop a method for trajectory propagation that better reflects the energy consumption of the system.

SUMMARY: In this work a method was developed for the solution of the equations of motion of an object acted upon by several gravitational masses. In general, the motion can be described by a special class (for which y_ is missing) of second order initial value problems (IVPs).
$Y''(x) = f(x, y(x)), y(0) = y0, y'(0) = y'0.$
The numerical integration methods for this can be divided into two distinct classes:

(a) problems for which the solution period is known (even approximately) in advance;
(b) problems for which the period is not known.

Here only some methods of the second class were considered. Numerical methods of Runge-Kutta type as well as linear multi-step methods can be found in the literature. Our idea here is to develop a new method that conserves the energy per unit mass in the case of perturbation-free right and use the energy in

other cases to approximate the angular variation. The generalization to cases were the energy is not conserved is given. Numerical experiments for both cases were computed and the solution to well established methods was compared.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Space Vehicles, Modeling and Simulation

KEYWORDS: Orbit Determination, Numerical Algorithms

DEPARTMENT OF APPLIED MATHEMATICS

2001
Faculty Publications and Presentations

JOURNAL PAPERS

Fahroo, F. and Ross, I.M., "A Second Look at Approximating Differential Inclusions," *Journal of Guidance, Control and Dynamics*, Vol. 24, No. 1, pp. 131-133, 2001.

Fahroo, F. and Ross, I.M., "Costate Estimation by a Legendre Pseudospectral Method," *Journal of Guidance, Control and Dynamics*, Vol. 24, No. 2, pp. 270-277, 2001.

Gordis, J.H. and Neta, B., "Fast Transient Analysis for Locally Nonlinear Structures by Recursive Block Convolution," *ASME Journal of Vibrations and Acoustics*, Vol. 123, pp. 545-547, 2001.

Kaminer, I., Kang, W., Yakimenko, O. and Pascoal, A.M., "Application of Nonlinear Filtering to Navigation System Design Using Passive Sensors," *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 37, pp. 158-172, 2001.

Kang, W., Sparks, A. and Banda, S., "Coordinated Control of Multi-Satellite Systems," *AIAA Journal of Guidance, Control and Dynamics*, Vol. 24, No. 2, pp. 360-368, 2001.

Knorr, J.B. and Neta, B., "Plotting Circularly Polarized Field Patterns Using Processed NEC 4 Output Files," *Applied Computational Electromagnetic Society Newsletter*, Vol. 16, No. 2, pp. 26-33, 2001.

CONFERENCE PUBLICATIONS

Chang, D.E., Kang, W. and Krener, A.J., "Normal Forms and Bifurcations of Control Systems," *Proceedings of the IEEE Conference on Decision and Control*, Sydney, Australia, 12-15 December 2000.

Hamzi, B. and Kang, W., "Resonant Terms in a Class of Systems with Stationary Bifurcation," *Proceedings of the IEEE Conference on Decision and Control*, Orlando, FL, 4-7 December 2001.

Hamzi, B., Kang, W. and Barbot, J.P., "On the Control of Hopf Bifurcations," *Proceedings of the IEEE Conference on Decision and Control*, Sydney, Australia, 12-15 December 2000.

Kang, W. and Song, M., "Manufacturing Planning Based on Information Feedback," *Proceedings of the 6th International Conference on Control, Automation, Robotics and Vision*, Singapore, 5-8 December 2000.

Kang, W., Xi, N. and Sparks, A., "Theory and Applications of Formation Control in a Perceptive Referenced Frame," *Proceedings of the IEEE Conference on Decision and Control*, Sydney, Australia, 12-15 December 2000.

Kang, W., "Normal Forms, Invariants and Bifurcations of Nonlinear Control Systems," *Proceedings of the 3rd Workshop of Nonlinear Control Network, Bifurcation and Control*, Kloster Irsee, Germany, 1-3 April 2001.

Kang, W., Yeh, H. and Sparks, A., "Coordinated Control of Relative Attitude for Satellite Formation," *Proceedings of the AIAA Guidence, Navigation, and Control Conference*, 6-9 August 2001.

Nelson, E., Sparks, A. and Kang, W., "Coordinated Nonlinear Tracking Control for Satellite Formations," *Proceedings of the AIAA Guidence, Navigation, and Control Conference*, 6-9 August 2001.

Neta, B. and Ilan-Lipowski, Y., "A New Scheme For Trajectory Propagation," *Proceedings AIAA/AAS Astrodynamics Specialist Conference*, Quebec City, Quebec, Canada, Paper Number AAS 01-446, 31 July-3 August 2001.

Ross, I.M., Yan, H. and Fahroo, F., "A Curiously Outlandish Problem in Orbital Mechanics," ASS/AIAA Astrodynamics Specialist Conference, Paper AAS 01-430, Quebec City, Quebec, Canada, 30 July–22 August 2001.

Ross, I.M. and Fahroo, F., "A Pseudospectral Transformation of the Covectors of Optimal Control Systems," *Proceedings of the 1st IFAC/IEEE Symposium on System Structure and Control*, Prague, Czech Republic, August 2001.

Ross, I.M. and Fahroo, F., "Convergence of Pseudospectral Discretizations of Optimal Control Problems," *Proceedings of the 40th Conference on Decision and Control*, Orlando, FL, December 2001.

Yan, H., Fahroo, F. and Ross, I. M., "Optimal Feedback Control Laws by Legendre Pseudospectral Approximations," *Proceedings of the American Control Conference 2001*, Arlington, VA, June 2001.

Xiao, M. and Kang, W., "Bifurcation Control Using Integral Averaging Method," *Proceedings of the IEEE Conference on Decision and Control*, Sydney, Australia, 12-15 December 2000.

CONFERENCE PRESENTATIONS

Mansager, B., "A Combat Simulation Analysis of Autonomous Legged Underwater Vehicles," Second Joint Australian/American Conference on the Technologies of Mine Countermeasures, Randwick Army Barracks, Sydney, Australia.

Mansager, B., "The Utility of Fire and Forget Technology Demonstrated Using 1-meter Terrain," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD.

BOOKS

M. J. Holler and G. Owen (eds.), *Power Indices and Coalition Formation*, Boston (Kluwer), 2001.

CHAPTERS IN BOOKS

Owen, G., "Game Theory," *International Encyclopedia of the Social & Behavioral Sciences*, N.J. Smelser and Paul B. Baltes (eds.), Pergamon, Oxford, pp. 5863-5868, 2001.

DEPARTMENT OF MECHANICAL ENGINEERING

TERRY MCNELLEY
CHAIR

MECHANICAL ENGINEERING

OVERVIEW:

The mission of the Department of Mechanical Engineering is to increase the combat effectiveness of U.S. and Allied armed forces and to enhance the security of the United States through advanced education that focuses on the ability to identify, formulate and solve technical and engineering problems in areas related to mechanical engineering and that spans issues of research, design, development, procurement, operation, maintenance and disposal of components and systems for Naval platforms.

RESEARCH MISSION:

The research mission of the Department of Mechanical Engineering is to increase the combat effectiveness of U.S. and Allied armed forces and to enhance the security of the United States through research in areas related to mechanical engineering and that spans the field from basic phenomena to engineering design, development, operation, maintenance and disposal of components and systems for Naval platforms.

CURRICULA SERVED:

The Mechanical Engineering Department serves the Naval and Mechanical Engineering Curriculum (570) and the Mechanical and Reactors Engineering Curriculum (571). Both curricula are in support of Navy needs for individuals having advanced technical education in mechanical engineering and related fields. The 570 Curriculum provides the educational component for the Engineering Duty Officer program and the research program in the Department is designed to support the requirement for Officers having the ability to identify, formulate and solve technical and engineering problems in areas related to mechanical engineering.

DEGREES GRANTED:

- Master of Science in Mechanical Engineering
- Mechanical Engineer
- Doctor of Philosophy
- Doctor of Engineering

RESEARCH THRUSTS:

There are five different disciplines of research thrusts such as Fluid Dynamics, Heat Transfer and Turbomachinery; Dynamics Systems, Controls and Robotics; Solid Mechanics, Vibrations, and Shock; Materials Science and Engineering; Total Ship Systems Engineering

FACULTY EXPERTISE:

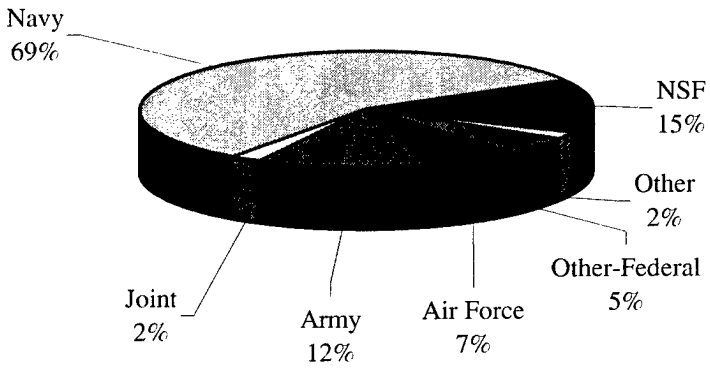
- Fluid Dynamics, Heat Transfer and Turbomachinery:
  Distinguished Professor Turgut Sarpkaya, Professor Matthew Kelleher, Associate Professor Knox Millsaps, Jr., Associate Professor Ashok Gopinath
- Dynamics Systems, Controls and Robotics:
  Professor Anthony Healey, Professor Morris Driels, Associate Professor Fotis Papoulias
- Solid Mechanics, Vibration, and Shock:
  Professor Young Shin, Professor Young Kwon, Associate Professor Joshua Gordis
- Materials Science and Engineering:
  Professor Terry McNelley, Professor Alan Fox, Associate Professor Indranath Dutta
- Total Ship Systems Engineering:
  Professor Charles Calvano

RESEARCH FACILITIES:

The Mechanical Engineering Laboratories are designed as complements to the educational mission and research interests of the department. In addition to extensive facilities for the support of student and faculty research, a variety of general use equipment is available. This includes equipment and facilities for the investigation of problems in engineering mechanics; a completely equipped materials science laboratory, including advanced scanning electron microscopes, an Auger microprobe, a transmission electron microscope and X-ray diffractometers; an oscillating water tunnel, a unique underwater towing tank and a low turbulence water channel; a vibration analysis laboratory; a fluid power controls laboratory; a robotics and real-time control laboratory; facilities for experimentation with low velocity air flows; equipment for instruction in thermal transport phenomena; a laser doppler velocimeter; nuclear radiation detection equipment and an interactive CAD/CAE computer graphics laboratory. Experimentation is further enhanced by a broad selection of analog and digital data acquisition and processing equipment and instrumentation.

RESEARCH PROGRAM (Research and Academic)-FY2001:

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



Size of Program: **$1158K**

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JMEM AIR TO SURFACE TASKS 3,8,16

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: U.S. Army Material System Analysis Activity and Naval Postgraduate School

OBJECTIVE: To improve delivery accuracy methodology and to develop a real time DA capability.

SUMMARY: The first part of the project was to develop a spreadsheet that would compute delivery accuracy of unguided weapons. This was accomplished with the assistance of LT T. Smith. The second part was to begin translating this methodology into a c++ environment capable of being integrated directly into JAWS. The third task related to the analysis of accuracy for the AGM-65 Maverick missile, and the calculation of accuracy parameters for the JAWS program.

THESES DIRECTED:

Smith, T., "Real Time Computation of the Delivery Accuracy for Air Launched Unguided Weapons," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Bombing Accuracy, Weaponeering

REVIEW AND IMPLEMENTATION OF MOUT DOCUMENTATION AND METHODOLOGY

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: U.S. Army Training Analysis Command-Monterey

OBJECTIVE: Review Army and SOF documents dealing with methodologies applying to MOUT.

SUMMARY: This was a small start up project to review available documentation for a proposal into the application of the Acquire target acquisition model to the MOUT environment. An FY02 proposal was submitted and subsequently approved.

THESES DIRECTED:

Leach, D., "Weaponeering Small Boats," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Target Acquisition, MOUT, Combat Modeling

WHITE PAPER ON THE JTCG/ME TRAINING AND EDUCATION REQUIREMENTS

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: U.S. Army Material System Analysis Activity

OBJECTIVE: To review the education and training requirements stemming from JTCG products and recommend a suggest a strategy for improvement.

SUMMARY: The JTCG/ME produces many operational products for all military services. At present training and education relating to these products is uncoordinated and sparse. The white paper will review existing training and educational programs relating to these products, identify potential shortcomings and recommend a strategy for improvement.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software, Education and Training, Weaponeering

INTERFACIAL SLIDING IN MULTI-COMPONENT SYSTEMS

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation

OBJECTIVE: To investigate the mechanisms of creep at interfaces of dissimilar materials.

SUMMARY: The goal of this project is to develop a phenomenological understanding of the mechanisms operative during sliding of interfaces at high temperatures. A combination of experimental and analytical means are being utilized to investigate the kinetics of interfacial sliding and its effect on thin film systems.

PUBLICATIONS:

Dutta, I., Chen, M.W., Peterson, K. and Shultz, T., "Plastic Deformation and Interfacial Sliding in Al and Cu Thin Film: Si Substrate Systems Due to Thermal Cycling," *Journal of Electronic Packaging*, Vol. 30, pp. 1537-1548, 2001.

Nagarajan, R. and Dutta, I., "A Novel Approach for Optimizing the Fracture Toughness of Precipitation-Hardenable Al-SiCp Composites," *Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science*, Vol. 32, pp. 433-436, 2001.

Dutta, I., Peterson, K. and Chen, M.W., "Plasticity and Interfacial Sliding in Cu Thin Film: Si Substrate Systems During Thermal Cycling," *Plasticity, Damage and Fracture at Macro, Micro and Nano Scales*, A.S. Khan and O. Lopez-Pamies, eds., *Proceedings Ninth International Symposium on Plasticity*, NEAT Press, pp. 117-119, 2002.

PRESENTATIONS:

Dutta, I., Chen, M.W., Peterson, K. and Shultz, T., "Interfacial Sliding at Thin Film: Semiconductor Substrate During Thermal Cycling," presented at the 130th Annual Meeting of the Minerals, Metals and Materials Society of AIME, New Orleans, LA, 11-15 February 2001.

THESES DIRECTED:

Shultz, T., "A Hot-Stage Atomic Force Microscope for Measuring Plastic Deformation in Thin Films on Silicon During Thermal Cycling," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Composite, Multi-layers, Thin Films, Creep, Interfacial Sliding

THERMO-MECHANICAL BEHAVIOR OF SOLDER JOINTS FOR ELECTRONIC PACKAGING

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To obtain a mechanistic understanding of the relationship between microstructural coarsening and applied constraints during thermo-mechanical cycling of solder joints.

SUMMARY: Flip Chip and Ball Grid Array solder joints in electronic packaging applications are subjected to large imposed strains and temperature variations during service conditions. During cycling, the microstructure coarsens, plastic strains localize, and the solder joint eventually fails by low-cycle fatigue induced by permanent creep deformation. The purpose of this project is to understand the dependence of micrsotructural coarsening on the plastic strain state in a solder joint during thermo-mechanical cycling.

PUBLICATIONS:

Dutta, I., Gopinath, A. and Marshall, C., "Underfill Constraint effects during Thermo-Mechanical Cycling of Flip Chip Solder Joints," *Journal of Electronic Packaging*, in press (accepted November 2001, to appear in April 2002).

Dutta, I., "A Constitutive Model for Creep of Lead-Free Solders Undergoing In-situ Microstructural Coarsening: A First Report," *Journal of Electronic Packaging*, in review.

THESES DIRECTED:

Marshall, C., "Effect of Underfill Constraint during Thermo-Mechanical Cycling of Flip Chip Solder Joints under Shear," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Electronic Packaging, Solder, Thermal Cycling, Deformation

COMPOSITIONAL AND MICROSTRUCTURAL ANALYSIS OF ADVANCED ULTRA-LOW CARBON WELDMENTS

Alan G. Fox, Professor
Department of Mechanical Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: The objective of this work (which commenced in FY99) is to quantatively advance the ability to understand, predict and control microstructural evolution and mechanical behavior in advanced, low carbon steel weldments produced with new ultra-low carbon (ULC) filler metals. In particular, the goal is to elucidate the effects of weld chemistry and weld thermal processing history on compositional, microstrutural and mechanical properties variations across weldments and amongst different weldments and to use the experimental results both as input to, and as a direct quantative test of detailed weld simulation models developed at NRL.

SUMMARY: The work at NPS will involve the use of high resolution analytical transmission electron microscopy to determine the microstructure and microchemistry as a function of position within different ULC weldments particularly with respect to carbon in the weld metal and oxygen in the non-metallic inclusions generated as a result of the welding process.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: HSLA Steels, Welding, Ultra-Low Carbon Steel Weld, Electron Microscopy

THERMOFLUID AND THERMOMECHANICAL ISSUES IN ELECTRONIC PACKAGING

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To investigate the thermofluid and thermomechanical aspects of the electronic packaging of flip chips from a reliability viewpoint.

SUMMARY: This project was a continuation of the collaboration initiated in CY-2000 with Professor I. Dutta (also of the Department of Mechanical Engineering). Different topical areas were covered as follows:

(a) The flow characteristics of a liquid epoxy encapsulant designed as an underfill for flip chip devices was experimentally studied in a controlled manner. The area coverage by the underfill in capillary flow was measured as a function of chip bump pattern, point of application of underfill, and environment temperature. Observations of flow front uniformity and void formation were recorded which provide useful fundamental insight into the fluid filling challenges posed by continually reducing chip size.

(b) The effect of cycling of a localized heat source on the underside of a flip chip package die was studied in order to explore the possible formation of hot spots in the package resulting from heat flow inhibiting interfacial defects due to imperfect thermal contacts at key locations. An energy partitioning model was used to evaluate the reliability of the solder joints under such accelerated thermal fatigue cycling loads. The effects of different peak heat flux values, and thermal boundary conditions were investigated. The thermal results clearly show pronounced temperature gradients that can be induced within the package. The associated structural results applied to the damage model show that creep continues to be the primary mechanism of failure in the package.

(c) The role of underfill constraint in thermomechanical cycling was investigated in a controlled single joint shear experimental study to determine the extent of load transfer from the solder to the encapsulant. A finite element model was used to corroborate the essential deformation characteristics of the joint, and to provide insight into the experiments. The strain response of the solder joint was found to be significantly influenced by microstructural coarsening, which is countered by the hydrostatic stresses imposed by the underfill on the joint.

PUBLICATIONS:

Dutta, I., Gopinath, A. and Marshall, C., "Underfill Constraint Effects during Thermo-Mechanical Cycling of Flip Chip Solder Joints," due to appear in the *Journal of Electronic Materials.*

Dunne, J.E., Smith, V.E., Gopinath, A. and Dutta, I., "Modeling the Effects of Cycling of a Localized Heat Source on a FCOC with Defects," to be presented at the 52nd ECTC.

THESES DIRECTED:

Wennersten, S.M., "Flow Characteristics of Liquid Epoxy Underfill in a Narrow Gap for Flip Chip Devices," Masters Thesis, Naval Postgraduate School, March 2001.

Smith, V.E., "A Finite Element Analysis of Thermal Fatigue Stresses in the Solder Joints of a Flip Chip Package," Masters Thesis, Naval Postgraduate School, September 2001.

Dunne, J.E., "Modeling the Effect of Cycling of a Localized Heat Source in the Die of a Flip Chip Package with Defects," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Other (Electronic Packaging)

KEYWORDS: Flip Chip, Electronic Packaging, Thermomechanical Fatigue, Underfill, Capillary Flow

TURBINE CONVECTIVE COOLING CONCEPTS EVALUATION

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Air Warfare Center – Aircraft Division and
Defense Advanced Research Projects Agency

OBJECTIVE: To provide support and validatory analyses of ongoing work in a new MEMs-based micro-heat exchanger turbine cooling concept.

SUMMARY: This project is a new start in FY-2001. The primary thrust of the project was to develop a multi-physics computational analysis of the proposed heat exchanger design. The micro-heat exchanger is based on the concept of the use of pin fins in the narrow gap of a shroud enclosed turbine blade. A finite element numerical analysis based on the package ANSYS has been initiated to predict the flow and heat transfer characteristics of such a micro pin fin heat exchanger. In such a short pin fin enclosed array configuration, both the pins and the end wall make substantial contributions to the heat transfer which need to be identified. For the small pin fin size relative to the blade radius of curvature, a planar model was assumed and a fully three dimensional numerical analysis was carried out. Various streamwise and spanwise pin fin spacings were used to determine both row-averaged and array-averaged heat transfer coefficients for the heat exchanger. A range of flow Reynolds numbers was covered and the results corroborated with available data in the literature. The heat transfer performance was compared with overall pressure drop characteristics to predict an optimal configuration.

PUBLICATIONS:

Adametz, D.S., Hamilton, L.J. and Gopinath, A., "Numerical Analysis of the Performance of a Staggered Cross-Pin Array Heat Exchanger," to be presented at the 8th AIAA/ASME Joint Conference.

THESES DIRECTED:

Adametz, D.S., "Numerical Analysis of Heat Exchanger Performance for a Staggered Short Pin-Fin Array," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Pin-Fin Array, Compact Heat Exchanger, Micro Heat Exchanger, Turbine Blade Cooling

EVALUATION OF COOLING TECHNOLOGIES FOR MAGNETORESTRICTIVE ACTUATORS

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center – Carderock Division

OBJECTIVE: To evaluate available cooling technologies that would work within the design constraints of magnetorestrictive actuators and maintain operating temperatures below a safe threshold.

SUMMARY: This project was a short term piece of work for NSWC carried out in CY-2001. The goal of the project was to investigate and recommend possible cooling technologies that would maintain the temperature of magnetorestrictive actuators under safe operating limits. After exploring various options, and keeping the design constraints in mind, it was recommended that for baseline use simple low maintenance off the shelf heat exchanger components with no moving parts be used for robust and reliable performance of the actuator in the harsh environments envisioned. It was found that the basic cooling needs could be met with an extended surface natural convection cooling design such as a press fitted pin fin assembly. The working constraints were that the ambient temperature could be a high as 35°C while the actuator temperature was not to exceed 95°C, and that the final package was to fit within a cylindrical package of dimensions no more than one foot in length and diameter. Sample baseline calculations were provided for a typical case of an assembly of 35 circular/annular aluminum fins that could provide a heat transfer rate of as much as 650°W. In addition, active cooling enhancement strategies were recommended through the use of vortex tubes that work off standard high pressure air lines to provide a jet/stream/curtain of cold air. It was suggested that strategically located vortex tubes could be used to provide an empirically calibrated blast(s) of cold air on the actuator along the length of its travel to maintain its temperature within safe operating limits.

PUBLICATIONS:

Gopinath, A., "Evaluation of Cooling Technologies for Magnetorestrictive Actuators," Technical Report.

DoD KEY TECHNOLOGY AREA: Other (Cooling Technologies)

KEYWORDS: Magnetorestrictive Actuator, Natural Convection, Fin Assembly, Vortex Tubes

EFFICIENT NONLINEAR TRANSIENT DYNAMIC ANALYSIS FOR STRUCTURAL OPTIMIZATION USING AND EXACT INTEGRAL EQUATION FORMULATION

Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Beny Neta, Professor
Department of Applied Mathematics
Sponsor: National Science Foundation

OBJECTIVE: This project is concerned with the theoretical development and computational implementation of a time domain theory for locally nonlinear transient structural synthesis. Application principally will be made to seismic isolation.

SUMMARY: This research concerns the continued development of a time domain theory for structural synthesis. This theory provides the previously unavailable capability of performing exact damped transient structural synthesis for systems with localized nonlinear components with the order of the synthesis being independent of model size. The method is based on Volterra integral equations derived from the convolution integral which describe substructure coupling and structural modification. Current results demonstrate an order of magnitude reduction in compute times as compared with widely-used commercial finite element analysis packages. The use of the formulation for the optimal design of seismic isolation is under development. The algorithm has been extended to treat nonlinear memory-type elements (e.g. elastoplastic hysteretic).

PUBLICATIONS:

Gordis, J.H. and Neta, B.,"Fast Transient Analysis for Locally Nonlinear Structures by Recursive Block Convolution," *ASME Journal of Vibration and Acoustics*, Vol. 123, No. 4. pp. 545-547, 2001.

THESIS DIRECTED:

Jarque, A.V., "Recursive Block-by-Block Integral Equation Solution for Transient Dynamic Analysis with Memory Type Elements," Masters Thesis, Naval Postgraduate School, March 2001.

Norton, K.M., "Parameter Optimization of Seismic Isolator Models Using Recursive Block-by-Block Nonlinear Transient Structural Synthesis," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Structural Dynamics, Transient Response, Nonlinear Dynamics, Seismic Isolation

DESIGN OF LAB-SCALE MODEL TEST OF ISOLATION FOR ROLL-ON ROLL-OFF (RORO) RAMP

Joshua H. Gordis, Associate Professor
Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The objective of this project was to perform frequency response analysis of the DTMB runs 1-503 and NRL runs 1-217 of the T-ACS seakeeping experiments.

SUMMARY: In Sea State 3 and above, the stern ramp of the Cape T ship is vulnerable to an overstress condition when off-loading vehicles. Therefore, there exists a need to design motion-compensation devices ("isolation") which when placed between the end of the ramp and the barge, precludes the possibility of a ramp overstress condition. Parallel to analytical studies conducted under separate funding, there is a need to establish an accurate and cost-efficient experimental set-up in order to validate the theoretical models. This need is addressed in this work. A basic experimental configuration has been designed and built. Actual testing and data analysis is set to begin during the month of February. Further data analysis and conclusions along with recommendations of the most promising designs will be reported during this year.

THESES DIRECTED:

Trevisan, R.A., "Development of Experimental Facility for Roll-On Roll-Off Ramp Isolation Dynamics," Master Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, Vibration Isolation, Testing and Evaluation

MOTION MINIMIZATION IN HIGH SPEED TOWING OPERATIONS

Joshua H. Gordis, Associate Professor
Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Office of Naval Research

OBJECTIVE: The objective of this project was to support the Office of Naval Research in further development of the novel SLICE hull form with a trailer hull.

SUMMARY: The focus of this project was on a hinge connection between the "tractor" and "trailer" SLICE vessels. This provides a number of technical challenges in high-speed high sea state ocean towing systems that have not been studied in the past. A model describing the dynamics of the two bodies under tow was developed. A series of runs was conducted in order to gain some insight into the seakeeping behaviors of the two ships. A generic spring/damper connection was assumed to exist at the interface. Current studies aim at more realistic configurations, along with the establishment of a design and analysis procedure in order to quantify the performance degradation in a seaway. A simulation model for low frequency motions was also developed, and a comprehensive stability analysis is underway.

THESES DIRECTED:

Nash, C., "Vertical Plane Response of Surface Ships in Close Proximity Towing," Masters Thesis, Naval Postgraduate School, June 2001.

Jones, G.D., "Semi-Rigid Maneuvering Model for Analysis of Maneuvering in the Horizontal Plane," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Towing, Seakeeping

REDUCING RAMP STRESS LEVELS VIA SEMI-ACTIVE DAMPING

Joshua H. Gordis, Associate Professor
Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The current ramp design used in roll-on roll-off (RORO) operations has been determined to be structurally inadequate in sea state 3. The overall objective of this continuing project is to determine the isolation properties that are required in order to reduce ramp stress levels below the allowable for worst-case loading.

SUMMARY: A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, was developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. Preliminary parametric studies, utilizing a standard second order model for the frequency response properties of the connecting body, of the response amplitude operator of the ramp motion were performed for varying wave directions and isolator stiffness and damping. These were utilized for random wave analysis in standard fully developed seas. The results indicated that rational selection of isolator properties could result in significant reduction of motions and stress levels in the connecting ramp. Current efforts include incorporation of actual FEM results coupled with the existing hydrodynamic prediction models.

THESES DIRECTED:

Buckley, J.E., "Computational Mechanics of the Full-Scale and Model-Scale Roll-On, Roll-Off (RORO) Stern Ramp and Experimental Modal Analysis of the Model-Scale Ramp and Support," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

STUDIES IN INTELLIGENT CONTROL OF AUTONOMOUS VEHICLES

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Ford Motor Company

OBJECTIVE: This grant is in the support of research in the subject matter and serves to aid the ongoing programs in the Center for Autonomous Underwater Vehicle Research.

SUMMARY: This project has supported the purchase of radio ethernet communications devices and radio modem connections between the *ARIES* robot and a shore based operator station. Also, it has supported the purchase of mobile laboratory equipment necessary to the deployment of *ARIES* in Monterey Bay.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles, Ships and Watercraft

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Navigation

HYDRO-THERMAL VENT MAPPING WITH MULTIPLE AUTONOMOUS UNDERWATER VEHICLES (AUV)

Anthony J. Healey, Professor
Department of Mechanical Engineering
D. B. Marco
Center for Autonomous Underwater Vehicle Research
A. Pascoal
University of Lisbon, Lisbon, Portugal
Sponsor: Office of Naval Research

OBJECTIVE: The IST has been conducting missions in the Azores using a surface catamaran vehicle (*DELFIM*) with plans to add an underwater vehicle (*MARIUS*). NPS will provide the cooperating underwater vehicle *ARIES* which has a video capability and an acoustic modem for underwater communications.

The approach for mapping these shallow water vent areas will be to employ an echo sounder on the *DELFIM* to provide bathymetry and detect the presence and general location of clusters of vents. *DELFIM* will communicate the cluster location data information by acoustic and radio modems to the NPS *ARIES* AUV. The *ARIES* will have the capability to reacquire the vent area using its DGPS / Doppler / IMU navigational suite, and to conduct a survey of the local area with a video camera. *ARIES* will provide geo-located video images of the vents, taken from a slow speed local search at constant altitude.

A joint exercise was conducted with IST, NPS, and the University of the Azores during the month of August near the Island of Faial, Azores. The detail objectives were:

- Demonstrate two vehicle underwater communications.
- Obtain video confirmation of shallow water hydro-thermal vent activity using video with location obtained from an independent source.

SUMMARY:

- Navigational accuracy mostly errors < 5m obtained with GPS popup.
- Video acquisition obtained of vent area given position from an independent source. Vent bubbles were found.
- Acoustic communications between *DELFIM* and *ARIES* with FAU modem where each vehicle was operated under autonomous control.
- All commands were received successfully and acted upon with no retransmits. The commands were sent from the support ship to the *DELFIM* and then to *ARIES*. Ranges up to 700m with 2 vehicles underway.

For this mission, a pair of acoustic modems were installed on the *ARIES* and on the IST *DEFIM* autonomous surface craft. Two laptop computers were used on the research vessel *ARQUIPELAGO* and are referred to as the base station systems. One laptop is used for command and control directly to the *ARIES* controlling computer through a radio link while the vehicle is surfaced. The second laptop is a two part link using both radio and acoustic modem communications. Radio communications are used from the *ARQUIPELAGO* surface ship to the *DELFIM*, at which point the data is sent to an acoustic modem mounted below the craft and allows communications with the *ARIES* while it is submerged.

The current configuration of the acoustic modem allows sending character strings up to 256 characters in length per transmit. For reasons of future compatibility across different systems, NMEA style ASCII strings are used as a standard format for the messages defined. The general form of all messages sent or received from the modem are of the form:

PUBLICATION:

Healey, A.J., Marco, D.B. and Pascoal, A.M., *Hydro-Thermal Vent Mapping with Multiple AUVs: AZORES-2001*, Naval Postgraduate School Technical Report, NPS-ME-01-007.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles, Ships and Watercraft

KEYWORDS: Autonomous Underwater Vehicles, AUV, Hydro-thermal Vent Mapping

TACTICAL DECISION AIDS USING MODELING AND SIMULATION

Anthony J. Healey, Professor
Department of Mechanical Engineering
Jane Wu, Contractor
Don P. Brutzman, Associate Professor
Department of Information Science
Sponsor: Office of Naval Research

OBJECTIVE: The goals are to develop Tactical Decision Aids for using small autonomous underwater vehicles (AUVs) in very shallow water (VSW) environments. TDAs enable operators to view data gathered by these vehicles and make informed decisions as to the conduct of mine countermeasures operations.

The current tactical decision aids system used by the U.S. Navy for mine countermeasures is a system named MEDAL (Mine Warfare Environmental Decision Aids Library). MEDAL is a software package running inside the GCCS-M global command and control system used by Navy ships. It is used to evaluate asset positions, minelike contacts, snippet images of contacts, snippet images of those contacts later identified as mines, and bathymetry maps. Other data such as bottom typing may be displayed if available. The objectives include the timely gathering of AUV data, converting, archiving, and translating it into the form familiar in MEDAL to Naval operational personnel. The goal is to improve the timeliness of data gathering including the post processing of sonar and video images for import into MEDAL. Long term goals are to integrate 3D visualization of data to enhance decision making, particularly in regard to deciding whether a contact is in fact a mine.

One issue in this project is how to deal with data from unclassified assets that are in development from university institutions, translate into the form used by MEDAL, and import the results into the classified Navy systems used in the fleet. To this end we have defined an automated data server system (ADS) that is linked through a local area network (LAN) to a stand alone MEDAL system. The MEDAL system runs on a TAC4 or better HP workstation. At the present time, it only runs on the HP systems with the 10.20 OS and the GCCS-M operating system. The ADS has been refined and is now interactive through screen entry from an operator. Future versions will be automated without operator intervention so that the software could run inside the control system of the AUVs. The ADS allows the operator to view data through a VRML 3D viewer in which models of vehicles and contacts can be seen thereby extending MEDAL into 3-D views.

SUMMARY: The initial version of the ADS has been developed and demonstrated during both Fleet Battle Exercise Hotel and its rehearsal. This initial version uses operator intervention to gather and translate AUV data into MEDAL format. During the demonstrations, data gathered from the *REMUS* (SHARV), *Morpheous*, and *Drake* vehicles included track positions, bathymetry (water column depth) at each track point, and, after sonar and video data processing, the image files (jpeg / gif) for contacts and their locations. The data were converted into MTF message formats and imported into MEDAL. MEDAL data was available for the fleet operators to view and plan tasking for the vehicles.

Work conducted in FY 2001 included:

- purchase of a fast HP workstation to better allow display of bathymetry data files
- preparation and on site data gathering and display support for the Kernal Blitz 01 exercise in March at Camp Pendleton
- conducting a test with the NPS *ARIES* AUV with an aerial relay link to transmit data files from the surfaced vehicle to the command center.

An HP C3600 workstation was purchased and a version of MEDAL Build 7 was set-up running in an external drive. The data bases have been transferred in part from last years exercise - FBE-Hotel. In the new configuration, the data flow from the NPS ADS software is through a LAN coonnection, but there is still no direct connectivity between the post-processing workstations for the AUVs and the ADS. We developed a LAN connection with the *REMUS* console, but other vehicles such as the *BPAUV* were operated off shore and had no ability to transmit data back to the command and control center.

In addition to data gathering, and during the KB01 exercise held at Camp Pendleton March 2001, a series of experiments was run with the *ARIES* underwater vehicle (http://www.cs.nps.navy.mil/research/auv/auvframes.html), it's support boat, (a Boston whaler), the *PELICAN* aircraft, and the control station at the ONR base. The objective was to transfer an image file pre-stored on the *ARIES* AUV, through

the aircraft to the ONR base while the aircraft was flying an AROSS sensor mission and investigate transmit rate for distances over several kilometers.

The *ARIES* was towed to site on "White Beach" and from 1:00pm March 17, til 3:00 March 17, 2001, Regular communication links were obtained between the ARIES on board computers and the ONR base station set up on the Camp Pendleton BOQ.

PUBLICATION:

Healey, A.J., Wu, J. and Brutzman, D.B., "Tactical Decision Aids Using Modeling and Simulation," Ocean Engineering and Marine Systems Report 2000, ONR 32100-1, pp. 221-224, December 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Undersurface Vehicles - Ships and Watercraft

KEYWORDS: Underwater Robotics, Mine Countermeasures, Modeling and Simulation, Graphics, Physics Based Models

MODELING OF FIRE AND SMOKE PROPAGATION IN SHIPBOARD SPACES

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: The overall objective of this work is to investigate the effects of survivability considerations on the design of ships. Specifically work has been continuing to investigate the modeling of smoke propagation in shipboard compartments and passageways. It is very important that an understanding of the propagation of fire and smoke in the various shipboard spaces be developed and that some means be developed to apply that understanding to incorporate survivability considerations in the design of future combatants and to the development of fire fighting procedures.

SUMMARY: The propagation of fire-generated smoke with a counter-flow air supply in a horizontal arrangement of shipboard compartments and passageways was modeled using a computational fluid dynamics program generated by Computational Fluid Dynamics Research Corporation. This study was based on a large-scale live fire experiment performed by Naval Research Laboratory on the ex-*USS SHADWELL*. All simulations were evaluated at steady state conditions. A constant velocity counter-flow air supply was introduced into the model structure. The counter-flow air velocities used were 0.5, 1, and 2 m/s. This study used a Computational Fluid Dynamics combustion module to simulate a 620 kW fire generated by the complete combustion of propene gas from a burn pan in the space. Carbon dioxide from the fire was tracked throughout the structure to model smoke propagation. Seven simulations were performed with adiabatic and isothermal bulkhead, deck and overhead boundary conditions. Simulation smoke propagation results were consistent with experimental observations. Figures depicting temperature distribution, carbon dioxide distribution and mixture flow patterns at specified locations are provided in the report. The goal of this study is to evaluate the effectiveness of computational fluid dynamics modeling of smoke propagation in a shipboard space with a counter-flow air supply.

THESES DIRECTED:

Farman, G.J., "Modeling of Shipboard Smoke Propagation with a Forced Counter-Flow Air Supply," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Fire Propagation, Smoke Spread, Ship Survivability, Damage Control

INVESTIGATION OF THE USE OF ARTIFICIAL NEURAL NETWORKS IN HEAT TRANSFER

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The objective of this study is to investigate the feasibility of employing the neural network technique as a method of using experimental data to predict heat transfer behavior. Currently, data is acquired by experimentation, collected, and then correlated to one or more of the controllable inputs using some physical and mathematical insight. Experimental uncertainties in the data accumulation are coupled with the inherent uncertainties in the mathematical correlation

It is the goal to use neural networks, to make the predictions of thermal fluid behavior more reliable, less reliant on assumptions, and provide easier methods of evaluating these predictions. With neural networks all of the above goals are possible.

SUMMARY: Artificial neural networks have been employed to develop a predictive algorithm using experimental heat transfer data for a complex situation. The from a series of experiments investigating the boiling heat transfer from a vertical bank of tubes in refrigerant 114 with variable amounts of oil present has been used to illustrate the process. Both finned and unfinned tubes were investigated. The network was trained with a partial set of the available data. The prediction obtained using the trained network was then compared to the remaining experimental data. The artificial neural network provided an excellent predictive method.

PUBLICATIONS:

Kelleher, M.D., Cronley, T.J., Yang, K.T. and Sen, M., "Using Artificial Neural Networks to Develop a Predictive Method from Complex Experimental Heat Transfer Data," *Proceedings of the International Mechanical Engineering Congress*, New York, NY, November 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Artificial Neural Networks

MODELING AND SIMULATION OF DAMAGE AND CRACKS IN PARTICULATE COMPOSITE MATERIALS: EFFECTS OF PRESSURE LOADING

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsors: Air Force Research Laboratory and Naval Postgraduate School

OBJECTIVE: This was a continuing research project from past several years during which a numerical modeling and simulation technique, called a multi-level (micro-macro) technique, had been developed and evaluated against experimental results. This year's effort was to study the effect of pressure loading on damage initiation and growth and to model the effect in the damage mechanics.

SUMMARY: The stress-strain behavior of a particulate composite specimen under hydrostatic pressure was modeled using the multi-scale approach. The approach was developed in the past by the investigator. The damage was described at the micro-level analysis in terms of the respective damage of each constituent material. In the present study, a damage theory was developed based on the two components of strain energy density: dilatational and deviatoric energy densities. The dilatational energy associated with the hydrostatic pressure was assumed to hold back the damage initiation. As a result, a damage theory including the hydrostatic pressure effect was developed and tested against experimental data of a specimen with the star-shaped opening. The stress-strain curves predicted from the theory agreed well with the experimental curves.

The initial crack sizes at notch tips were predicted and compared to the experimental results with or without initial hydrostatic pressure. The predicted values compared very well to the test data. The crack

formation occurred either at the root of the large semi-circular notch or at the root of the smaller radius section which connected the large semi-circular section and the straight section. The two locations competed each other. The sizes and locations of initial cracks were in good agreement between the experimental and numerical results.

PUBLICATIONS:

Kwon, Y.W. and Craugh, L.E., "Progressive Failure Modeling in Notched Cross-Ply Fibrous Composites," *Applied Composite Materials*, Vol. 8, No. 1, pp. 63-74, January 2001.

Kwon, Y.W. and Liu, C.T., "Effect of Particle Distribution on Initial Cracks Forming from Notch Tips of Composites with Hard Particles Embedded in a Soft Matrix," *Composites, Part B: Engineering*, Vol. 32, pp. 199-208, 2001.

Kwon, Y.W., "Multi-level Approach for Failure in Woven Fabric Composites," *Advanced Engineering Materials*, Vol. 3, No. 9, pp. 713-717, 2001. (Invited Paper)

Kwon, Y.W. and Altekin, A., "Multi-level, Micro-Macro Approach for Analysis of Woven Fabric Composites," *Journal of Composite Materials*, accepted for publication.

Kwon, Y.W. and Lannamann, D.L., "Dynamic Modeling and Simulation of Interfacial Cracks in Sandwich Structures for Damage Detection," *Journal of Sandwich Structures and Materials*, accepted for publication.

Kwon, Y.W., "Multi-Scale, Multi-Level, Micro/Macro-Approach for Progressive Damage in Composite Structures," A Europe/USA Initiative on: The Structural Integrity of Composite Materials and Structures, Isle of Capri, Italy, May 2001. (Invited paper)

Kwon, Y.W. and Eren, H., "Boundary Element Analysis of Fiber/Matrix Interface," International Conference on Computational Engineering and Sciences, Puerto Vallarta, Mexico, August 2001.

Kwon, Y.W. and Liu, C.T., "Effect of Hydrostatic Pressure on Damage in Particulate Composites," Recent Advances in Solids and Structures -2001, IMECE 2001, CD-ROM Vol. 3, PVP-25201, 2001.

THESIS DIRECTED:

Altekin, A., "Multi-level Technique for Stiffness and Strength Calculations of Woven Fabric Composite Plate and Shell Structures," Masters Thesis, Naval Postgraduate School, June 2001.

Lannamann, D.L., "Structural Health Monitoring: Numerical Damage Predictor for Composite Structure," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power, Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Particle Reinforced Composite, Solid Rocket Propellant, Damage and Crack, Modeling and Simulation, Initial Crack Size, Hydrostatic Pressure

MODELING AND SIMULATION OF THE HUMAN THORAX UNDER BULLET IMPACT

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: Armed Forces Institute of Pathology

OBJECTIVE: This was a continuing research project from the previous years. This year's effort was to model the human thorax especially including major internal organs with protective body armors hit by high-speed bullets in order to evaluate potential injury.

SUMMARY: The finite element analysis model was developed for the human thorax of skeleton with internal organs. The skeleton includes ribs, sternum, vertebrae, vertebral discs, facet joints, costal cartilages, muscle, etc. while internal organs include the lung, heart, trachea, etc. Two different body armors, one with a Kevlar vest and the other with a vest and armor plate, were also modeled. The results of the computer model were compared to the experimental data obtained with human cadavers with body armors hit by bullets. In the model, the measured speed of the bullet was used. The comparison of accelerations in the sternums, spines, lung, and heart were very good. The pressure inside the heart compared well between the experimental and numerical results. Those results provided reliability of the developed computer model. The program was extended to include the head and neck injury including brain damage.

PUBLICATION:

Kwon, Y.W. and Lobouno, J.A., "Biodynamics of Human Thorax with Body Armors Subject to Ballistic Impact," Recent Advances in Solids and Structures -2001, IMECE 2001, CD-ROM Vol. 3, PVP-25206, 2001.

Lobuono, J.A. and Kwon, Y.W., *Biodynamical Response of the Human Thorax to a Projectile Impact*, Naval Postgraduate School Technical Report, NPS-ME-01-001, March 2001.

THESIS DIRECTED:

Lobuono, J.A., "Biodynamical Response of the Human Thorax to a Projectile Impact," Masters Thesis, Naval Postgraduate School, March 2001.

George, D.N., "Finite Element Modeling of the Human Head and Neck for Injury," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Finite Element Method, Human Thorax Model, Body Armors, Dynamic Response

UNIT-CELL MODEL OF OPEN METALLIC FOAM

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: This project was to develop a unit-cell model to compute the effective strength and stiffness of an open-cell metallic foam structure.

SUMMARY: Representative unit-cell models were developed for open cell metallic foams in order to predict their effective elastic moduli and the plastic collapse strengths. Two different open-cell metallic foams were considered. One was just open cell foam and the other was open cell foam filled with an elastic material. The models were based on the metallic frames consisting of edges of tetrakaidecahedron. The filling material was modeled as elastic foundation to the ligament frames. The frame structure of the unit-

cell was analyzed using the finite element method. The plastic collapse strength was determined when the joints of ligaments became plastic hinges under the assumption of elastic-perfectly plastic material behavior of the metallic material. Both elastic modulus and plastic collapse strength were computed using a single step of finite element analysis without any iterative or incremental procedure. In addition, a very small number of finite elements was used. As a result, the unit-cell is computationally very efficient. In order to assess the representative unit-cell models, experiments were also conducted. The experimental data agreed very well with the predicted values of both stiffness and strength.

PUBLICATION:

Kwon, Y.W. and Cooke, R.E., "Representative Unit-Cell Model for Open-Cell Metal Foam," submitted to *Materials Science and Engineering A*, 2001.

THESES DIRECTED:

Cooke, R.E., "Finite Element Modeling of Metal Foam Structures Subject to Compressive Loading," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Metal Foam, Open-Cell, Unit-Cell Model, Effective Stiffness and Strength

MECHANICAL AND MICROSTRUCTURAL CHARACTERIZATION OF COMMERCIAL AA5083 MATERIALS

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: University of Texas - Austin and GM Research and Development Center

OBJECTIVE: The goals of this program are: to characterize the fundamental deformation mechanisms in grain-refined AA5083 aluminum alloy material during elevated temperature deformation; and to characterize the failure mechanisms in materials from various sources.

SUMMARY: Our current understanding of microstructural refinement by deformation and recyrstallization is largely empirical and so the ability to predict and then produce refined microstructures for various purposes, such as superplasicity, is limited. Recently developed computer-aided electron backscatter diffraction analysis and orientation imaging microscopy (OIM) methods have been applied to the investigation of the mechanisms of grain refinement and grain boundary development during processing of AA5083. Materials have been examined following various thermomechanical treatments and deformation histories. Grain refinement occurs via particle stimulated nucleation of primary (discontinous) recrystallization resulting equiaxed grains, a nearly random texture, and random disorientation distribution. During elevated temperature deformation dislocation creep is indicated by the formation of a <111> fiber texture while grain boundary sliding is marked randomizing of the initial texture. Thus, local deformation conditions can be monitored by texture analysis. Cavity formation can also be evaluated by OIM.

PUBLICATIONS:

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G. and Ruano, O.A., "Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," in *Proceedings of ICSAM 2000*, International Conference on Superplasticity in Advanced Materials, (N. Chandra, ed.), Materials Science Forum, Trans Tech, Zurich, pp. 255-260, 2001.

Eddahbi, M., McNelley, T.R. and Ruano, O.A., "The Evolution of Grain Boundary Character during Superplastic Deformation of an Al-6%Cu-0.4%Zr Alloy," *Metallurgical and Materials Transactions A*, Vol. 32A, pp.1093-1102, 2001.

Pérez-Prado, M.T., Swisher, D.L. and McNelley, T.R., "Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," in *Proceedings of THERMEC 2000*, International Conference on Processing and Manufacturing of Advanced Materials (T. Chandra, ed.) Elsevier, London, Section G2, 2001.

Pérez-Prado, M.T., González-Doncel, G., Ruano, O.A. and T.R. McNelley, "Texture Analysis of the Transition from Slip to Grain Boundary Sliding in a Discontinuously Recrystallized Superplastic Aluminum Alloy," *Acta Materialia*, Vol. 49, pp. 2259-68, 2001.

PRESENTATIONS:

McNelley, T.R., Harrell, J.W. and Taleff, E.M., "Application of Orientation Imaging Microscopy Methods to Superplastic Aluminum Alloys," presented in the International Symposium on Superplasticity and Superplastic Forming, Annual Fall Meeting of ASMI, Indianapolis, IN, 7 November 2001.

McNelley, T.R., "Deformation Mechanisms and Ductilities of AA5083 Materials II: Orientation Imaging Microscopy," invited seminar, General Motors Research and Development Center, Warren, MI, 24 August 2001.

THESIS DIRECTED:

Harrell, J.W., "Analysis of the Transition in Deformation Mechanisms in Superplastic 5083 Aluminum Alloys by Orientation Imaging Microscopy," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Aluminum, Superplasticity, Recrystallization, Grain Boundaries, Thermomechanical Processing

ULTRA-FINE AND NANO-GRAIN MICROSTRUCTURES BY SEVERE PLASTIC DEFORMATION

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to determine mechanisms by which ultra-fine grain structures form in severely deformed materials, such as those processed by equi-channel angular (ECA) pressing.

SUMMARY: Ultra-fine grain sizes in the sub-micrometer or even nanometer range can be achieved in metallic materials by imposing extremely large plastic strains during deformation processing. Such grain refinement will result in drastic improvements in strength/toughness combinations for structural application,s as well as in improved ductility during elevated temperature forming. Methods such as ECA pressing are required in order to impart stains large enough to produce such refinement. ECA pressing is accomplished by pressing a billet of material through a die having two channels, of equal cross section, that intersect at an angle. Such a billet experiences simple shear without change in cross-sectional area and so the process is amenable to repetition. Billet rotation between successive pressing operations allows the shear plane orientation to be changed in order to achieve further control of microstructural refinement. The characteristics of the grain structures and, especially, the nature of the grain boundaries produced by such processing have remained in question. However, grain-to-grain misorientations may be readily determined by newly developed computer-aided electron backscatter pattern (EBSP) analysis methods.

PUBLICATIONS:

McNelley, T.R. and Swisher, D.L., "Deformation Banding and Grain Boundaries in Aluminum and Aluminum Alloys," in *Modeling the Performance of Engineering Structural Materials II* (D.R. Lesuer and T.S. Srivatsan, eds.) TMS, Warrendale, PA, pp. 195-202, 2001.

McNelley, T.R., Swisher, D.L. and Pérez-Prado, M.T., "Deformation Bands and the Formation of High-Angle Grain Boundaries in a Superplastic Aluminum Alloy," *Metallurgical and Materials Transactions*, in press.

Terhune, S.D., Swisher, D.L., Oh-ishi, K., Horita, Z., Langdon, T.G. and McNelley, T.R., "An Investigation of Microstructure and Grain Boundary Evolution during ECA Pressing of Pure Aluminum," *Metallurgical and Materials Transactions*, in press.

PRESENTATIONS:

McNelley, T.R., Swisher, D.L. and Pérez-Prado, M.T., "Deformation Bands and the Formation of High-Angle Grain Boundaries in a Superplastic Aluminum Alloy," La Jolla / DoE Workshop on Creep and Creep Fracture, San Diego, CA, 27 June 2001.

McNelley, T.R. and Swisher, D.L., "Deformation Banding and Grain Boundaries in FCC Metals and Alloys," Symposium on Modeling the Performance of Structural Materials, Annual Fall Meeting of TMS, Indianapolis, IN, 6 November 2001.

McNelley, T.R., "Orientation Imaging Microscopy: Deformation-Induced Microstructures and Superplasticity in Aluminum Alloys," invited seminar, Department of Materials Science and Engineering, Kyushu University, Fukuoka, Japan, 28 July 2001.

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Aluminum, Grain Refinement, Nano-Grain Materials, Recrystallization, Grain Boundaries, Materials Processing

LOW OBSERVABLE MULTI-FUCTION STACK (LMS) EXHAUST GAS SUPPRESSION AND SUPPORT OF AT-SEA TRIALS

Knox T. Millsaps, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Weapon Center – Carderock Division

OBJECTIVE: To develop and demonstrate a gas turbine exhaust signature suppression system, which is capable of meeting specified infrared (IR) and radar cross-section (RCS) goals, under specific engine-imposed constraints and overall systems constraints that the system be integrated into a low observable topside.

SUMMARY: This was the final year of a 4-year advanced technology demonstrator (ATD) project to develop a low observable multi-function stack (LMS) as part of the series of ATDs to create integrated topside technology for the next generation of surface combatants. In previous years, the NPS part of this project was to create design concepts and develop supporting analytical codes for the preliminary design of enhanced mixing eductors, and to test and optimize cold-flow geometry for reducing plume radiation. These designs were next tested at larger scale at a hot-flow facility in Memphis with NPS assistance. Finally, last year the full-scale hardware was tested in an at-sea trial. NPS supplied engineering consulting services as well as integration advice throughout the project and was a member of the integrated product team (IPT).

PUBLICATIONS:

Ratcliffe, R., Imber, R., Bird, W. and Millsaps, K.T., "Test Report for LMS at Sea Trials," Report number not yet assigned. SECRET.

Ratcliffe, R., Imber, R., Bird, W. and Millsaps, K.T., "Final Report for the Low Observable Multi-Function Stack Advanced Technology Demonstrator Program," Report number not yet assigned. SECRET.

THESIS DIRECTED:

Markowicz, J.C., "Validation of Low Observable Stack Eductor Design for Gas Turbine Exhaust Systems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Other (Signature Control)

KEYWORDS: Propulsion, Signature, IR, Gas Turbines, Exhaust, Enhanced Mixing

REVIEW OF ADVANCED TECHNOLOGY GAS TURBINE RESEARCH AND DEVELOPMENT PROGRAMS

Knox T. Millsaps, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Systems Engineering Station

OBJECTIVE: To review and evaluate the current research and development program for the advanced technology gas turbine program for the U.S. Navy's surface fleet gas turbine life cycle manager and to make technical recommendations for program improvement.

SUMMARY: A review of the Condition Based Maintenance (CBM) program for gas turbines for both power and propulsion, which started in November of 2001, is in progress. The major area of interest is to develop a technology road map for interfacing component level engine CBM modules into the Navy's Integrated Condition Assessment System (ICAS). More specifically, a review of methods to determine degradation in compressor performance due to dirt and salt deposition is underway as is the modeling of sensor and performance measures.

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

KEYWORDS: Propulsion, Gas Turbines, Condition Based Maintenance (CBM), and Compressor Fouling

WEB-BASED NAVAL ARCHITECTURE FOR PD-21

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Center for Naval Education and Training

OBJECTIVE: The purpose of this project was to develop a web based class on Naval Architecture in support of the PD21 and the TSSE programs.

SUMMARY: The purpose of this project was to develop a web based class on Naval Architecture in support of the PD21 and the TSSE programs. The outcome of this project was the development of a comprehensive web site on Naval Architecture, with over two thousand files, incorporating text, graphs, support information material, and fully interactive examples. The site is fully integrated into the Blackboard web based delivery system adopted by NPS.

OTHER:

A fully functional web site, in essence an electronic textbook on Naval Architecture.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Manpower, Personnel and Training.

KEYWORDS: Naval Architecture, Web-based Instruction, Javascript

EXTENDED STATE SPACE MODELING OF RRDF INTERFACE

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The goal of this project was to develop a model in order to bridge the gap between existing constant coefficient time domain and more accurate hydrodynamic models.

SUMMARY: A mathematical model describing the fundamental dynamics in the interface problem between a ship, a barge, and a connecting ramp was developed and solved. The hydrodynamics for the ship and the barge were described by a 12-degree of freedom fully coupled model, which was based on potential theory and incorporated proximity effects. Ramp structural dynamics were studied by a finite element model, which was calibrated based on detailed studies of commercially available codes. The models were coupled together through a spring/damper and the solution of the system was obtained in both regular waves and a representative sea state. Parametric studies with regards to different coupling conditions proved that optimization based on either relative motions or ramp maximum stress is possible.

THESES DIRECTED:

Dalakos, A., "A Coupled Hydrodynamic/Structural Model for Ship/Barge/Ramp Interface," Masters Thesis, Naval Postgraduate School, December 2001.

Trevisan, R., "Development of Experimental Facility for Roll-On Roll-Off Ramp Isolation Dynamics," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

MOTION MINIMIZATION IN HIGH SPEED TOWING OPERATIONS

Fotis A. Papoulias, Associate Professor
Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Funding: Office of Naval Research

OBJECTIVE: The objective of this project was to support the Office of Naval Research in further development of the novel SLICE hull form with a trailer hull.

SUMMARY: The focus of this project was on a hinge connection between the "tractor" and "trailer" SLICE vessels. This provides a number of technical challenges in high-speed high sea state ocean towing systems that have not been studied in the past. A model describing the dynamics of the two bodies under tow was developed. A series of runs was conducted in order to gain some insight into the seakeeping behaviors of the two ships. A generic spring/damper connection was assumed to exist at the interface. Current studies aim at more realistic configurations, along with the establishment of a design and analysis

procedure in order to quantify the performance degradation in a seaway. A simulation model for low frequency motions was also developed, and a comprehensive stability analysis is underway.

THESES DIRECTED:

Nash, C., "Vertical Plane Response of Surface Ships in Close Proximity Towing," Masters Thesis, Naval Postgraduate School, June 2001.

Jones, G., "Semi-Rigid Maneuvering Model for Analysis of Maneuvering in the Horizontal Plane," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Towing, Seakeeping

MECHANISM OF SPRAY GENERATION AT THE FREE SURFACE OF LIQUID JETS

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: This continuing basic research is an experimental investigation of the ligament and drop formation at the free surface of liquid wall jets, flowing over smooth and sand-roughened plates towards the understanding of the physics of droplet formation, in general, and of the spray formation on bow-sheets, in particular.

SUMMARY: Measurements were made with several high-speed imagers, a pulsating laser, and a Digital Particle Image Velocimeter (DPIV) system and analyzed through the use of appropriate software. The wall-jet Reynolds number ranged from 2.4×10^4 to 4×10^4, the Froude number from 15 to 30, and the Weber number from 1,500 to 3,000. The characteristics of the ligament forest and droplets were determined from the digitized images. Principal Investigator was invited to deliver two papers at two ONR meetings: at CALTECH in April 01 and in San Diego in September 01.

PUBLICATIONS:

Sarpkaya, T. and Merrill, C.F., "Spray Generation from Turbulent Plane Water Wall Jets Discharging into Quiescent Air," *American Institute of Aeronautics and Astronautics Journal*, Vol. 39, No. 7, pp. 1217-1229, July 2001.

Sarpkaya, T. and Merrill, G., "Spray Formation at the Free Surface of Liquid Wall Jets," *Naval Hydrodynamics*, Vol. 22, pp. 145-154, October 1999.

THESIS DIRECTED:

Markle, H.B., "An Experimental Investigation of the Bow Wave on USS Cole (DDG-67)," Masters Thesis, Naval Postgraduate School, September 2001.

Osgood, D.B., "Flow About Perforated Bodies," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Hydrodynamics, Drop Formation, Spray

OPTIMIZATION OF SUBMERGED SENSOR STABILITY

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: To provide expert advice and make recommendations to improve and/or optimize the stability of sensors immersed in earth's magnetic field at the ocean bottom as part of deployable autonomous distributed system (as part of a deployable autonomous distributed system). Review the final report of SNWSC and offer advice for improvement.

SUMMARY: The Space and Naval Warfare Systems Center San Diego (SSC SD) is tasked by the Deployable Autonomous Distributed Systems Demonstration (DADS-D) project to mitigate sensor noise caused by hydrodynamic effects. The immediate concern is the extreme sensitivity of the of fluxgate magnetometers (housed in sea-floor packages) to motion due to surface waves, currents, and the passage of non-naval bodies. This investigator has identified the nature of the relevant hydrodynamic disturbances, the hydrodynamic forces acting on a sensor package, effects of sensor proximity to the seafloor, any data in the literature relevant to the shape of the sensor package, and the frequency phenomena related to vortex shedding and surface waves.

PUBLICATIONS:

Sarpkaya, T., "Final Report to SPAWAR on the Wave-Current Interaction of Fluxgate Magnetometers," August 2001.

Sarpkaya, T., "On the Force Decompositions of Lighthill and Morison," *Journal of Fluids and Structures*, Vol. 15, No. 2, pp. 227-233, Feburary 2001.

Sarpkaya, T., "Hydrodynamic Damping and Quasi-Coherent Structures at Large Stokes Numbers," *Journal of Fluids and Structures*, Vol. 15, No.7, pp. 909-928, 2001.

Sarpkaya, T., "Experiments on the Stability of Sinusoidally Oscillating Flow over a Circular Cylinder," to appear in *Journal of Fluid Mechanics*, Vol. 457, pp. 157-180, 2002.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Sensors, Unsteady Flows, Stability, Frequency Response

REVIEW OF HYDRODYNAMIC LOADS ON SPECIFIC STRAINERS

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: U.S. Nuclear Regulatory Commission

OBJECTIVE: To review the appropriate topical reports and any other relevant data on hydrodynamic loads on structures submerged in the pressure suppression pools of boiling-water nuclear reactors. The ultimate purpose of these reviews and detailed analyses is to provide sound technical advice to NRC on unsteady flow about specific types of strainers and, in particular, on the prevailing Keulegan-Carpenter numbers and acceleration drag loads so that NRC can perform its regulatory duties in the light of the expert opinion and complete its review of the strainers under their consideration.

SUMMARY: A thorough study of about 3,000-page reports and papers led to the conclusion that the determination of the typical values of the Keulegan-Carpenter number, K, and the acceleration drag coefficient, C_m, for the conditions expected following a loss-of-coolant accident (LOCA) and safety/relief valve (SRV) discharge requires the load carrying capacities (LCCs) of the strainers, the positions of the largest stresses on the strainers and/or their attachments; the velocities, accelerations, (their magnitudes and directions) and their distribution throughout the suppression pool during the first few seconds of LOCA and

SRV. In summary, the existing analyses and experiments are inadequate for the assessment of the safety of the strainers in Boiling-Water Nuclear Reactors. Proper analyses and experiments have been performed to provide sound technical guidance to NRC towards the fulfillment of its regulatory duties.

PUBLICATIONS:

Sarpkaya, T., "Final Technical Evaluation Report to NRC," 25 April 2001.

Sarpkaya, T., "On the Force Decompositions of Lighthill and Morison," *Journal of Fluids and Structures*, Vol. 15, No. 2, pp. 227-233, February 2001.

THESIS DIRECTED:

Osgood, D.B., "Flow About Perforated Bodies," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Nuclear Reactors, Inertial Force, Perforated Bodies, Unsteady Flow

THE WAKE MODELING AND PREDICTION FOR AVOSS

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration - Langley Research Center

OBJECTIVE: The purpose of the investigation was (a) to develop a new vortex decay model for the prediction of the descent of aircraft trailing vortices subjected to realistic environmental conditions (stratification, turbulence, cross wind, headwind, shear effects, and ground effect), and (b) to apply the model to field data obtained with Lidar in Memphis and Dallas–Fort Worth airports.

SUMMARY: A robust and relatively simple physics-based vortex decay model has been devised. It does not violate any hydrodynamical principles, has only one model constant, uses the turbulence eddy dissipation rate in conjunction with a theoretical model (as verified by experiments and numerical simulations), and it requires no cumbersome algorithms to account for the ground effects. Acquisition of better and more detailed field data (vortex velocities and positions; wind, shear and their gradients; better temperature, humidity, and eddy dissipation profiles), the quantification of the consequences of unstable stratification, and the optimization of the new model parameters constitute the essence of this continuing research of vital international importance. The model has been successfully tested at the Dallas-Fort Worth airport in September 2001. It is now being patented by NASA, (Sarpkaya as one of the four inventors who has devised the theoretical model and carried out the vortex-decay experiments).

PUBLICATIONS:

Sarpkaya, T., Robins, R.E. and Delisi, D.P., "Wake-Vortex Eddy- Dissipation Model Predictions Compared with Observations," *Journal of Aircraft (AIAA)*, Vol. 38, No. 4, pp. 687-692, July-August 2001.

Sarpkaya, T., "New Model for Vortex Decay in the Atmosphere," *Journal of Aircraft (AIAA)*, Vol. 37, No. 1, pp. 53-61, January/February 2000.

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering*, Vol. 10, No. 4, pp. 1053-5381, December 2000.

OTHER:

The model has now been incorporated into NASA's AVOSS program for the management of aircraft landings at large airports (JFK, Memphis, DFW, New Orleans). Sarpkaya is cited as one of the inventors of the model by NASA.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Trailing Vortices, Aircraft Wakes, Wake Hazard

VORTEX BREAKDOWN IN TURBULENT SWIRLING FLOWS

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation and Naval Postgraduate School

OBJECTIVE: Vortex breakdown is the transformation of a slender vortex into three-dimensional forms. Where, how, and under what circumstances does this transformation occur in viscous vortical flows constitute the essence of the breakdown problem. Neither a stagnation point, nor a region of reversed flow, nor the bridging of laminar–turbulent states is necessary. Trailing vortices, swirling flows in pipes, vortical flows above sweptback wings at large angles-of-attack, flows in closed containers with a rotating lid, and columnar vortices in atmosphere may experience breakdown. Where, how, and under what circumstances does the breakdown occur in viscous vortical flows constitute the essence of the investigation.

SUMMARY: The definition of the spectral characteristics of the conical region is the subject of the ongoing investigation. The mean velocities and turbulence intensities were measured in forward-scattering mode with a three-component Laser Doppler Anemometer. The results refute the conjectures that the circumstances of breakdown are insensitive to the Reynolds number and the local turbulence properties. These two factors have a strong influence on the evolution of the flow. Of all the known forms, the spiral emerges as the most fundamental breakdown form. All other forms may be regarded as transient states affected by various types of instabilities. At very high Reynolds numbers the breakdown acquires forms and characteristics never seen before: Extremely high rates of revolution, onset of core-bifurcation or core-trifurcation, intense nonisotropic turbulence, and a conical shape.

PUBLICATIONS:

Sarpkaya, T., "Discovery and Evolution of Vortex Breakdown Phenomena," *Progress in AeroSpace Sciences* (in print, 2002).

Novak, F. and Sarpkaya, T., "Vortex Breakdown at High Reynolds Numbers," *American Institute of Aeronautics and Astronautics Journal*, Vol. 38, No. 5, pp. 1671-1679, May 2000.

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

KEYWORDS: Vortex Breakdown, Vorticity, Swirling Flow

FRAGMENTATION AND DETONATION OF ANTIPERSONNEL MINE AND SURVIVABILITY OF SENSORS IN THE GRIZZLY

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: U.S. Army Tank Automotive Command

OBJECTIVE: The Grizzly has various sensors including control sensors, laser systems, hydraulic lines, wires and various cameras mounted on the Grizzly armor hull which is exposed to various types of landmine detonation. The objective is to study the detonation and fragmentation process of mine such as

OMZ-72 antipersonnel mine and to extend the study on effect of shock wave and fragmentation to the survivability of sensors, laser systems, cameras, wires and hydraulic lines exposed to the threat. Based on the results investigated, NPS will provide design guidance on protecting sensors, laser systems, wires and hydraulic lines, etc, from the threat. The pop-up anti-personnel mines such as the OZM-72 has unique and of interesting features about its horizontal dispersion of fragmentation. The project results will provide design guidance from a better understanding of the threat.

SUMMARY: Many obstacles such as minefields, barbwire entanglements, tank ditches and other fortifications are used to paralyze the forward momentum of mechanized armed forces. To combat this the Grizzly tracked vehicle was developed for the United States Army to defeat these complex obstacles and clear mine fields. Due to its intended mission various sensors, laser systems, hydraulic lines, wires and cameras are mounted on the armor hull, which are exposed to various types of landmine detonation and fragmentation.

This study is to model an OZM – 72 bounding antipersonnel mine to be used in studying the effects of shock waves and fragmentation on the survivability of the equipment mounted on the Grizzly's armored hull. 2D and 3D finite element models of the antipersonnel mines are developed and used to simulate the detonation and fragmentation phenomena. The analysis results obtained from the models provide a basis from which design guidance can be formulated for protecting equipment or personnel from this threat.

PUBLICATIONS:

Kloster, M.S. and Shin, Y.S., "Modeling and Simulation of Detonation and Fragmentation of Anti-Personnel Mine," *Proceedings of 72nd Shock and Vibration Symposium*, Destin, FL, 12-16 November 2001.

THESES DIRECTED:

Kloster, M.S., "Coupled Lagrangian and Eulerian Approach to Detonation and Fragmentation Problems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: ALE Analysis, Fragmentation and Detonation, Land Mine

IMPACT ANALYSIS AND ACTIVE VIBRATION DAMPING ON ORBITAL VEHICLES

Young S. Shin, Professor
LT Timothy Barney, USN
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration - Dryden

OBJECTIVE: To develop a method to determine the location, force, and orientation of an impact on a space truss using a minimal distributed sensor grid. Also achieve improved active control of vibrations induced in the truss by installed equipment operating at a constant frequency. The active control is to be achieved using piezoelectric elements installed as truss members and should be able to control the vibration at multiple nodes and sensitive to various axis without relocating the active elements. A FEM of the truss, generated using ANSYS, is to be used to assess the ability to model the implementation of the control algorithm and will be compared to the actual experimental results.

SUMMARY: As spacecraft designs become more complex, compact, and lightweight, it becomes more likely that equipment induced vibrations will adversely affect other components. The use of either passive or active damping typically requires extensive system modeling and a significant weight addition. The Adaptive Multi-Layer LMS Controller, coupled with piezoelectric active elements has been able to suppress single axis vibration of a truss by greater than 50 dB. The algorithm has also proven to be flexible with respect to actuator orientation and location with respect to the desired point of suppression. The test platform was the NPS space truss, which is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment mounted at its extremities. One of two installed piezoelectric actuators and an

Adaptive Multi-Layer LMS control law were used to effectively eliminate an axial component of the vibrations induced by a linear proof mass actuator mounted at one end of the truss.

PUBLICATION:

Barney, T.A., Shin, Y.S., and Agrawal, B.N., *Adaptive Multi-Layer LMS Controller Design and Application to Active Vibration Suppression on a Truss and Proposed Impact Analysis Technique*, Naval Postgraduate School Technical Report, NPS-ME-01-002, June 2001.

THESIS DIRECTED:

Barney, T., "Impact Analysis and Active Vibration Damping on Orbital Vehicles," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Space Truss, Active Vibration Damping, Piezoelectric Elements, Impact Analysis, ANSYS, FEM Simulation of Active Control Method

DEPARTMENT OF MECHANICAL ENGINEERING

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Faculty Publications and Presentations

JOURNAL PAPERS

Chen, M.W., Dutta, I., Inoue, A., Zhang, T. and Sakurai, T., "Kinetic Evidence for the Structural Similarity between a Supercooled Liquid and an Icosahedral Phase in a $Zr_{65}Al_{7.5}Ni_{10}Cu_{7.5}Ag_{10}$ Bulk Metallic Glass," *Applied Physics Letters,* Vol. 79, pp. 42-44, 2001.

Dutta, I, Chen, M.W., Peterson, K. and Shultz, T., "Plastic Deformation and Interfacial Sliding in Al and Cu Thin Film: Si Substrate Systems Due to Thermal Cycling," *Journal of Electronic Packaging*, Vol. 30, pp. 1537-1548, 2001.

Eddahbi, M., McNelley, T.R. and Ruano, O.A., "The Evolution of Grain Boundary Character during Superplastic Deformation of an Al-6%Cu-0.4%Zr Alloy," *Metallurgical and Materials Transactions A*, Vol. 32A, pp. 1093-1102, 2001.

Gordis, J.H. and Neta, B. "Fast Transient Analysis for Locally Nonlinear Structures by Recursive Block Convolution," *ASME Journal of Vibration and Acoustics*, Vol. 123, No. 4. pp. 545-547, 2001.

Kang, W. and Papoulias, F., "Bifurcation and Control of Submersible Vehicles with Dive Plane Reversal," *International Journal of Latin American Applied Research*, Special Issue on Bifurcation Control, Vol. 31, No. 3., pp. 141-149, 2001.

Kwon, Y.W. and Craugh, L.E., "Progressive Failure Modeling in Notched Cross-Ply Fibrous Composites," *Applied Composite Materials*, Vol. 8, No. 1, pp. 63-74, January 2001.

Kwon, Y.W. and Liu, C.T., "Effect of Particle Distribution on Initial Cracks Forming from Notch Tips of Composites with Hard Particles Embedded in a Soft Matrix," *Composites, Part B: Engineering*, Vol. 32, pp. 199-208, 2001.

Kwon, Y.W., "Multi-level Approach for Failure in Woven Fabric Composites," *Advanced Engineering Materials*, Vol. 3, No. 9, pp. 713-717, 2001.

Kwon, Y.W. and McDermott, P.M., "Effects of Void Growth and Nucleation on Plastic Deformation of Plates Subjected to Fluid-Structure Interaction," *ASME Journal of Pressure Vessel Technology*, Vol. 123, pp. 480-485, November 2001.

Marco, D.B. and Healey, A.J., " Command Control and Navigational Results With the NPS *ARIES* AUV," *Journal of Oceanic Engineering*, Vol. 26, No. 4, pp. 466-476, October 2001.

Nagarajan, R. and Dutta, I., "A Novel Approach for Optimizing the Fracture Toughness of Precipitation-Hardenable Al-SiCp Composites," *Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science*, Vol. 32, pp. 433-436, 2001.

Pérez-Prado, M.T., González-Doncel, G., Ruano, O.A. and McNelley, T.R., "Texture Analysis of the Transition from Slip to Grain Boundary Sliding in a Discontinuously Recrystallized Superplastic Aluminum Alloy," *Acta Materialia*, Vol. 49, pp. 2259-68, 2001.

Sarpkaya, T., "Hydrodynamic Damping and Quasi-Coherent Structures at Large Stokes Numbers," *Journal of Fluids and Structures*, Vol. 15, No.7, pp. 909-928, 2001.

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering*, Vol. 10, No. 4, pp. 1053-5381, December 2000.

Sarpkaya, T., "On the Force Decompositions of Lighthill and Morison," *Journal of Fluids and Structures*, Vol. 15, No. 2, pp. 227-233, February 2001.

Sarpkaya, T. and Merrill, C.F., "Spray Generation from Turbulent Plane Water Wall Jets Discharging into Quiescent Air," *American Institute of Aeronautics and Astronautics Journal*, Vol. 39, No. 7, pp. 1217-1229, July 2001.

Sarpkaya, T., Robins, R.E. and Delisi, D.P., "Wake-Vortex Eddy- Dissipation Model Predictions Compared with Observations," *Journal of Aircraft, AIAA*, Vol. 38, No. 4, pp. 687-692, July-August 2001.

CONFERENCE PAPERS

Healey, A.J., "Application of Formation Control for Multi-Vehicle Robotic Minesweeping," *Proceedings of IEEE CDC*, Paper No. CDC01-INV3103, December 2001.

Kelleher, M.D., Cronley, T.J., Yang, K.T., and Sen, M., "Using Artificial Neural Networks to Develop a Predictive Method from Complex Experimental Heat Transfer Data," *Proceedings of the International Mechanical Engineering Congress*, New York, NY, November 2001.

Kloster, M.S. and Shin, Y.S., "Modeling and Simulation of Detonation and Fragmentation of Anti-Personnel Mine," *Proceedings of 72nd Shock and Vibration Symposium*, Destin, FL, 12-16 November 2001.

Kwon, Y.W. and Liu, C.T., "Effect of Hydrostatic Pressure on Damage in Particulate Composites," *Recent Advances in Solids and Structures -2001*, IMECE 2001, CD-ROM Vol. 3, PVP-25201, 2001.

Kwon, Y.W. and Lobouno, J.A., "Biodynamics of Human Thorax with Body Armors Subject to Ballistic Impact." *Recent Advances in Solids and Structures -2001*, IMECE 2001, CD-ROM Vol. 3, PVP-25206, 2001.

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G. and Ruano, O.A., "Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," *Proceedings of ICSAM 2000*, International Conference on Superplasticity in Advanced Materials, (N. Chandra, ed.), Materials Science Forum, Trans Tech, Zurich, pp. 255-260, 2001.

Pérez-Prado, M.T., Swisher, D.L. and McNelley, T.R., "Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," *Proceedings of THERMEC 2000*, International Conference on Processing and Manufacturing of Advanced Materials (T. Chandra, ed.) Elsevier, London, Section G2, 2001.

CONFERENCE PRESENTATION (WITHOUT PUBLICATION)

Dutta, I., Chen, M.W., Peterson, K. and Shultz, T., "Interfacial Sliding at Thin Film: Semiconductor Substrate During Thermal Cycling," 130th Annual Meeting of The Minerals, Metals and Materials Society of AIME, New Orleans, LA, 11-15 February 2001.

Kwon, Y.W., "Multi-Scale, Multi-Level, Micro/Macro-Approach for Progressive Damage in Composite Structures," A Europe/USA Initiative on: The Structural Integrity of Composite Materials and Structures, Isle of Capri, Italy, May 2001.

Kwon, Y.W. and Eren, H., "Boundary Element Analysis of Fiber/Matrix interface," International Conference on Computational Engineering and Sciences, Puerto Vallarta, Mexico, August 2001.

McNelley, T.R., Harrell, J.W. and Taleff, E.M., "Application of Orientation Imaging Microscopy Methods to Superplastic Aluminum Alloys," International Symposium on Superplasticity and Superplastic Forming, Annual Fall Meeting of ASMI, Indianapolis, IN, 7 November 2001.

McNelley, T.R., Swisher, D.L. and Pérez-Prado, M.T., "Deformation Bands and the Formation of High-Angle Grain Boundaries in a Superplastic Aluminum Alloy," La Jolla / DoE Workshop on Creep and Creep Fracture, San Diego, CA, 27 June 2001.

McNelley, T.R. and Swisher, D.L., "Deformation Banding and Grain Boundaries in FCC Metals and Alloys," Symposium on Modeling the Performance of Structural Materials, Annual Fall Meeting of TMS, Indianapolis, IN, 6 November 2001.

Millsaps, K.T., "Congressional Decision Process on Federal Funding of Science and Engineering Projects and Infrastructure," ASME Public Affairs Leadership Conference PALC, San Diego, CA, June 2001.

Millsaps, K.T., "Congressional Decision Process on Federal Funding of Science and Engineering Projects and Infrastructure," ASME Board on Government Affairs, September 2001.

MEETING ABSTRACTS

McNelley, T.R., Swisher, D.L. and Pérez-Prado, M.T., "Deformation Bands and the Formation of High-Angle Grain Boundaries in a Superplastic Aluminum Alloy," La Jolla / DoE Workshop on Creep and Creep Fracture, San Diego, CA, 27 June 2001.

McNelley, T.R. and Swisher, D.L., "Deformation Banding and Grain Boundaries in FCC Metals and Alloys," Symposium on Modeling the Performance of Structural Materials, Annual Fall Meeting of TMS, Indianapolis, IN, 6 November 2001.

McNelley, T.R., Harrell, J.W. and Taleff, E.M., "Application of Orientation Imaging Microscopy Methods to Superplastic Aluminum Alloys," International Symposium on Superplasticity and Superplastic Forming, Annual Fall Meeting of ASMI, Indianapolis, IN, 7 November 2001.

TECHNICAL REPORTS

Barney, T.A., Shin, Y.S. and Agrawal, B.N., *Adaptive Multi-Layer LMS Controller Design and Application to Active Vibration Suppression on a Truss and Proposed Impact Analysis Technique*, Naval Postgraduate School Technical Report, NPS-ME-01-002, June 2001.

Gopinath, A., *Evaluation of Cooling Technologies for Magnetorestrictive Actuators*, Technical Report.

Healey, A.J., Marco, D.B. and Pascoal, A.M., *Hydro-Thermal Vent Mapping with Multiple AUVs: AZORES-2001*, Naval Postgraduate School Technical Report, NPS-ME-01-007.

Healey, A.J., Wu, J. and Brutzman, D.B., *Tactical Decision Aids Using Modeling and Simulation*, Ocean Engineering and Marine Systems Report 2000, ONR 32100-1, pp. 221-224, December 2000.

Lobuono, J.A. and Kwon, Y.W., *Biodynamical Response of the Human Thorax to a Projectile Impact*, Naval Postgraduate School Technical Report, NPS-ME-01-001, March 2001.

CONTRIBUTION TO BOOKS

McNelley, T.R. and Swisher, D.L, "Deformation Banding and Grain Boundaries in Aluminum and Aluminum Alloys," *Modeling the Performance of Engineering Structural Materials II* (D.R. Lesuer and T.S. Srivatsan, eds.) TMS, Warrendale, PA, pp. 195-202, 2001.

McNelley, T.R., "Continuous Recrystallization in Grain Boundaries in a Superplastic Aluminum Alloy," Chapter 22, *Electron Backscatter Diffraction in Materials Science*, (A.J. Schwartz, M. Kumar and B.L. Adams, eds), Kluwer Academic / Plenum Publishers, New York, NY, pp. 277-90, 2000.

OTHER

Kwon, Y.W., Special Issue on Fluid-Solid Interaction, *ASME Journal of Pressure Vessel Technology*, Vol. 123, November 2001 (guest editor).

Kwon, Y.W. and Chung, H.H., "Recent Advances in Solids and Structures-2001," ASME PVP, 2001 ASME International Mechanical Engineering Congress and Exposition, ASME, New York, New York, 2001, eds. Kwon, Y.W. and Chung, H.H.

DEPARTMENT OF METEOROLOGY

CARLYLE WASH
CHAIR

METEOROLOGY

OVERVIEW:

The Department of Meteorology provides graduate-level instruction in the science of meteorology and its application in support of military operations. To maintain expertise and provide support to student theses, the faculty performs research in the Navy-relevant areas of synoptic and dynamic meteorology, remote sensing, numerical modeling, tropical meteorology, boundary layer meteorology, and environmental effects.

Over 40 years ago, NPS was responsible for the establishment and flourishing of a Navy operational command on its campus. In 1959, the Naval Oceanographic Command moved its numerical prediction center to Monterey as a new operational command, the Fleet Numerical Weather Central (now, Fleet Numerical Meteorology and Oceanography Center-FNMOC). The Navy chose to move FNMOC to Monterey to take advantage of the presence of NPS with its large assembly of science faculty who are intimately familiar with Navy operational problems in meteorology and oceanography. For similar reasons, the Navy Environmental Prediction Research Facility (now the Marine Meteorology Division of the Naval Research Laboratory-NRL-Monterey), moved to Monterey in 1971. This further augmentation of meteorological and oceanographic scientists in Monterey, has made it the center of Naval environmental science.

The consequences of these moves are the substantial involvement of NPS faculty in research projects at NRL-Monterey and the enhancement of operational capabilities at FNMOC. Furthermore, personnel from the latter two organizations are able to take advanced courses at NPS, and officer-students at NPS can engage in thesis research on "real-life" applications relating environmental parameters to Naval operations.

CURRICULA SERVED:

- Meteorology
- Meteorology and Physical Oceanography
- Space Systems Operations
- Space Systems Engineering
- Electronic Warfare

DEGREES GRANTED:

- Master of Science in Meteorology
- Master of Science in Meteorology and Physical Oceanography
- Doctor of Philosophy in Meteorology

RESEARCH THRUSTS:

- Synoptic, Mesoscale, and Coastal Meteorology:
  Distinguished Professor Russell Elsberry, Associate Professor Wendell Nuss, Professor Carlyle Wash, Research Assistant Professor Douglas Miller, Research Associate Professor Patrick Harr
- Numerical Weather Prediction (NWP):
  Professor Roger Williams, Research Associate Hway-Jen Chen, Research Assistant Professor Kevin Cheung, Research Assistant Professor Douglas Miller
- Environmental Analysis and Visualization:
  Research Associate Mary Jordan
- Air-Sea Interactions:
  Professor Kenneth Davidson, Professor Robert Haney, Research Associate Paul Frederickson
- Satellite and Ground Based Remote Sensing:
  Professor Phillip Durkee, Research Associate Kurt Nielsen
- Tropical Meteorology:
  Professor Chih-Pei Chang, Research Associate Hway-Chen, Research Associate Professor Patrick Harr, Research Assistant Professor Kevin Cheung

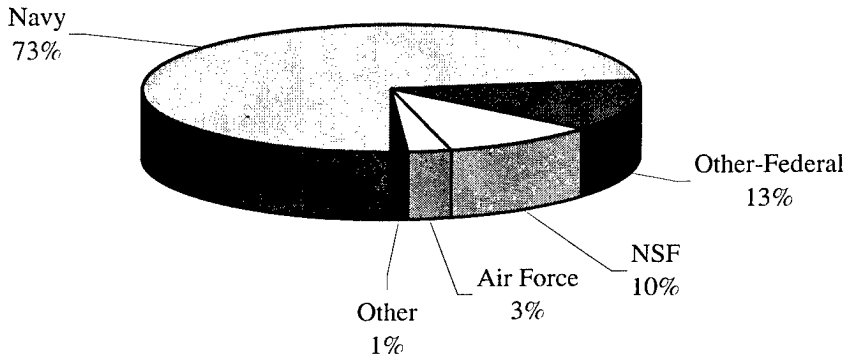
- Tropical Cyclone Motion:
  Distinguished Professor Russell Elsberry, Research Assistant Professor Kevin Cheung, Research Associate Professor Patrick Harr
- Boundary Layer Meteorology:
  Professor Kenneth Davidson, Associate Professor Qing Wang
- Climate Dynamics:
  Professor Chih-Pei Chang, Professor Roger Williams, Research Associate Hway-Jen Chen, Senior Lecturer Tom Murphee
- Atmospheric Factors in EM/EO Propagation:
  Professor Kenneth Davidson, Research Associate Professor Peter Guest, Research Associate Paul Fredrerickson
- Polar Meteorology:
  Research Associate Professor Peter Guest

RESEARCH FACILITIES:

- **IDEA Laboratory:** The Interactive Digital Environmental Analysis (IDEA) laboratory has Silicon Graphics workstations specifically designed and funded for instruction. The lab computers are used to analyze and display real-time satellite data and numerical model output.
- **Tactical Laboratory:** The Tactical Lab operates an SMQ-11 DMSP satellite receiver that collects and processes classified environmental data and runs military tactical decision aids used to support operations.
- **Synoptic Analysis and Forecasting Laboratory:** The Synoptic Analysis and Forecasting Lab uses a suite of computers and advanced display devices to provide local and global real-time meteorological data and numerical products for instruction and research in operational weather forecasting.
- **Atmospheric Boundary Layer Measurements Laboratory:** The Measurements Lab provides information from a special near-coastal observation site at Fort Ord in support of instruction and research in boundary layer and coastal meteorology. Present instrumentation includes two radar wind profilers, an automatic surface weather station, and rawinsonde systems.

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 Meteorology is provided below:



Size of Program: $2550K

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SYSTEMATIC APPROACH TO TROPICAL CYCLONE TRACK FORECASTING

Lester E. Carr, III, Research Associate Professor
Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this proposal is to provide Joint Typhoon Warning Center, Pearl Harbor, with the complete version of the systematic approach to tropical cyclone track forecasting, continue extension of the systematic approach to the other tropical cyclone basins, especially the Southern Hemisphere, Eastern/Central Pacific and the Atlantic regions.

SUMMARY: The Systematic Approach Forecasting Aid (SAFA) is an information management system to assist the forecaster in tropical cyclone track forecasting. This knowledge-based expert system has been developed over several years and was the subject of a beta test during 1999 (Carr et al, 2001). The first operational test of the SAFA system at the Joint Typhoon Warning Center (JTWC) in Hawaii was during the 2000 western North Pacific tropical cyclone season. A number of lessons-learned were gained from that test, both as to required SAFA system upgrades and the need for additional training materials. These items were the central focus of the effort in this project and the revised SAFA and improved training materials were delivered to JTWC during June 2001.

The second operational test during the 2001 western North Pacific season was a tremendous success. The JTWC 72-hour track forecast errors were 180 nautical miles compared to an expected value of 276 nautical miles based on the error reduction trend during the 1990s extrapolated to the year 2001. The post-season recap indicates that the SAFA system was applied more successfully and was clearly a major factor in the improved JTWC performance. Thus this project represents a successful transition of research to operations.

PUBLICATIONS:

Carr, L.E., III, R.L. Elsberry and J.E. Peak, 2001: Beta test of the Systematic Approach expert system prototype as a tropical cyclone track forecasting aid (SAFA). *Weather and Forecasting*, **16**, 355-368.

PRESENTATION:

Carr, L.E., III, R.L. Elsberry and M.A. Boothe, 2001: Status report on implementation of the Systematic Approach to tropical cyclone track Forecasting Aid (SAFA). 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January–1 February 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Tropical Cyclone Track Prediction, Tactical Decision Aids

DYNAMICS OF NORTHWEST PACIFIC TROPICAL DISTURBANCES AND MONSOON

Chih-Pei Chang, Professor
Roger Terry Williams, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: To study the interactions between Asia/Australian monsoon and tropical disturbances, particularly the dynamics of the formation and intensification of tropical disturbances in the monsoon confluence region in the Northwest Pacific.

SUMMARY: The interactions between monsoon circulations and tropical disturbances in the Northwest Pacific, where the low-level mean flow is westerly in the west and easterly in the east, are studied with a barotropic model. Model results suggest that the scale contraction by the confluent background flow, the nonlinear dynamics, the beta-effect, and the large-scale convergence are important for the energy and

enstrophy accumulation near the region where the zonal flow reverses. The energy/enstrophy accumulation can be maintained with a continuous Rossby wave emanation upstream. The largest accumulation occurs when the emanating zonal wavelength is around 2000 km. Longer Rossby waves experience less scale contraction and nonlinear effects while shorter Rossby waves cannot hold a coherent structure against dispersive effects.

The nonlinear energy/enstrophy accumulation mechanism is significantly different from previous linear energy accumulation theories. In the linear theories this is primarily accomplished by the slowdown of the Doppler-shifted group velocity through the convergence of mean zonal advection, while in nonlinear dynamics the contraction of the zonal wave scale plays the crucial role. More importantly, after the initial energy increase by the wave accumulation, linear dynamics will lead to an eventual loss of wave energy to the mean flow due to the increase of zonal wavenumber near the critical longitude. Thus, without the presence of other forcing processes such as diabatic heating, the disturbances will decay. In nonlinear dynamics, the sharpening of the vorticity gradient as the waves approach the confluence zone leads to the development of disturbance asymmetries with respect to the central latitude. This effect is through the nonlinear interaction of Rossby waves with the planetary vorticity gradient. This development leads to a pair of vorticity centers that straddles the central latitude with the cyclone (anticyclone) in the north (south), and an elongated, weak westerly flow along the central latitude. This elongated westerly flow, which possesses a zonal wavenumber smaller than that in the linear cases, reverses the sign of the Reynold's stress and allows the energy to grow near the critical longitude, leading to intensified disturbances.

With a more realistic monsoon-like background flow, a northwestward propagation pattern with an approximately 8-day period and 3000 km wavelength is produced, in general agreement with observed disturbances in the Northwest Pacific. The intensified disturbance may disperse energy upstream, leading to a series of trailing anticyclonic and cyclonic cells along the northwestward propagation path. When an opposing current is present, the energy dispersion leads to the formation of new disturbances in the confluence zone by a vortex axisymmetrization dynamics. Thus, results indicate that the scale contraction and nonlinear effects may cause a succession of tropical disturbances to develop without disturbance-scale diabatic effects.

PUBLICATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: Possible roles of Atlantic circulations on the weakening Indian Monsoon-ENSO relationship. 14, *J. Climate*, **14**, 2376-2380.

Kuo, H.-C., J.-H. Chen, R.T. Williams and C.-P. Chang, 2001: Rossby Waves in Zonally Opposing Mean Flow: Behavior in Northwest Pacific Summer Monsoon. *Journal of Atmospheric Science*, **58**,1035-1050.

Li, T., Y. Zhang, C.-P. Chang and B. Wang, 2001: On the relationship between Indian Ocean SST and Asian summer monsoon. *Geophysical Research Letter*, **28**, 2843-2846.

Li, T.B. Wang, C.-P. Chang, 2001: Theories on the tropospheric biennial oscillation: A review. *Dynamics of Atmospheric and Oceanic Circulations and Climate*, eds: M. Wang et al, Chinese Academy of Sciences, China Meteorological Press, Beijing, 872.

PRESENTATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: North Atlantic oscillation/arctic oscillation and the weakening Indian monsoon-ENSO relationship. NASA-IPRC-CLIVAR Workshop on Decadal Climate Variability, Manoa, HI, 8-12 January 2001.

Chang, C.-P. and T. Li, 2001: Monsoon-ENSO relationships and monsoon biennial variability. WMO International Conference on Monsoon Forecasting from Days to Years, Delhi, India, March 2001. (Invited)

Chang, C.-P., Z. Wang, J. Ju and T. Li, 2001: Interactions of maritime continent winter monsoon, ENSO and Indian Ocean winds. The Third International Symposium on Asian Monsoon System, Okinawa, Japan, 11-14 December 2001.

Kuo, H.-C. and C.-P. Chang, Rossby Waves in Zonally Opposing Mean Flow: Behavior in Northwest Pacific Summer Monsoon. The Third International Symposium on Asian Monsoon System, Okinawa, Japan, 11-14 December 2001.

THESIS DIRECTED:

Miller, H.A., "The Contribution of Symmetrization to the Intensification of Tropical Cyclones," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY: Battlespace Environments, Modeling and Simulation

KEYWORDS: Monsoon, West Pacific, Tropical Meteorology, Tropical Cyclones, Climate

EAST ASIA MONSOON AND TROPICAL BIENNIAL OSCILLATION SYSTEM (PCFS)

Chih-Pei Chang, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: This project studies the interannual variations of the East Asia Monsoon, and their relationship with the tropical biennial oscillation of the coupled atmosphere-ocean system.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Tropical Meteorology, Monsoon, Atmosphere-Ocean Interactions, Tropical Biennial Oscillation

FORECAST OF CLOUD PROBABILITY IN SOUTHEAST ASIA: DEVELOPMENT OF A PROBABILITY OF CLOUD FORECAST SYSTEM

Chih-Pei Chang, Professor
Department of Meteorology
Sponsors: Singapore Ministry of Defense

OBJECTIVE: To study the behavior and predictability of monsoon disturbances affecting East Asia and adjacent regions using Navy's regional numerical forecast model.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Cloud Forecast, Monsoon, Southeast Asia, South China Sea

MONSOON DISTURBANCES OVER THE CHINA SEAS

Chih-Pei Chang, Professor
Hway-Jen Chen, Research Associate
Department of Meteorology
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The objectives are: (1) to study the structure and the dynamic and thermodynamic properties of the disturbances in the vicinity of the Southeast and East Asian monsoon region that stretches from Indian Ocean to the tropical western Pacific, including the South China Sea and Yellow Sea, which are of particular interest to naval operations; and (2) to study the ability and sensitivity of Navy operational numerical models in analyzing and predicting these disturbances.

SUMMARY: In order to identify major inadequacies of COAMPS over the monsoonal tropical oceans numerical experiments were conducted to simulate the pre-monsoon onset case of 13-15 May 1998 during the South China Sea Monsoon Experiment (SCSMEX).

One of the major errors is the overestimate of rainfall in tropical Indian Ocean. COAMPS has two options of cumulus parameterization schemes: the Kain-Fritsch scheme and the Kuo scheme. In several experiments the Kuo scheme led to rapid false degeneration of most tropical systems, so the Kain-Fritsch scheme was chosen. (A coding error in the K-F scheme that artificially increases the precipitation was discovered in the course of the experiment and was corrected.)

The East China subtropical front and Indian Ocean tropical convection are considered two of the most important systems that affect the onset of the South China Sea summer monsoon (Lau et al 2000). The locations of these two systems were reasonably well forecasted. However, the forecast precipitation of the tropical system (south of India) was unrealistically excessive (>275 mm for the maximum 0-24 hr accumulated precipitation). This problem may be associated with cumulus parameterization or the sea surface temperature data. The Kain-Fritsch scheme was designed for the mid-latitude convective system. Preliminary results suggest two possible sources of problems. The first is the relationship between the precipitation efficiency and the wind shear used in Kain-Fritsch scheme, which now is an empirical function obtained from mid-latitude cases. The other is the lifetime of the convective cloud, which is reciprocal to the environmental wind speed. Since the wind speed over tropical area is relatively small, the lifetime of the convective cloud may be overestimated. Ways to resolve these issues are being studied.

PRESENTATIONS:

Chen, H.J. and C.-P. Chang, 2001: Report of a COAMPS bug that caused an overestimate of precipitation in subroutines "kfdrive.F" and "kfpara.F." Informal note to NRL Marine Meteorological Division, 11 July 2001.

Chen, J. M, T. Li. and C.-P. Chang: South China Sea SST regulations. International Scientific Conference on SCSMEX, Shanghai, April 2001.

Kuo, H.C. and C.-P. Chang, 2001: Tropical vortex development in Northwest Pacific monsoon. International Scientific Conference on SCSMEX, Shanghai, April 2001.

DoD KEY TECHNOLOGY: Battlespace Environments, Modeling and Simulation

KEYWORDS: Numerical Weather Prediction, Tropical Meteorology, Monsoon, China Seas

MONSOON – ENSO INTERACTIONS

Chih-Pei Chang, Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Administration

OBJECTIVE: To study the structure of the interannual variations of the Asian-Australian monsoon and its relationship with El Niño – Southern Oscillations (ENSO).

SUMMARY: The relationship between Asian monsoon and ENSO was studied using data analysis, simple dynamic modeling and numerical modeling. The studies reveal complex interactions between different climate parameters and underscore the variable nature of the relationships at different time scales, from biennial to interdecadal. In particular, the relationship between ENSO and the Indian monsoon rainfall appears to be affected by the decadal changes of the North Atlantic Oscillation/Arctic Oscillation, rather than changes of divergent circulations in the Pacific. The tropospheric biennial oscillations and ENSO are also affected differently by the Indian Ocean sea-surface temperature anomalies.

PUBLICATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: Possible roles of Atlantic circulations on the weakening Indian Monsoon-ENSO relationship. 14, *Journal of Climate*, **14**, 2376-2380.

Li, T., C.W. Tham and C.-P. Chang, 2001: A coupled Air-Sea-Monsoon oscillator for the TBO. *Journal of Climate*, **14**, 752-764.

Li, T., Y. Zhang, C.-P. Chang and B. Wang, 2001: On the relationship between Indian Ocean SST and Asian summer monsoon. *Geophysical Research Letters*, **28**, 2843-2846.

PRESENTATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: North Atlantic oscillation/Arctic oscillation and the weakening Indian Monsoon-ENSO relationship. NASA-IPRC-CLIVAR Workshop on Decadal Climate Variability, Manoa, HI, 8-12 January 2001.

Chang, C.-P., Interdecadal variations of the relationship between ENSO and the Asian monsoon. interdecadal and interannual variations of East Asian Monsoon, Taipei, March 2001. (Invited)

Chang, C.-P. and T. Li, 2001: Monsoon-ENSO relationships and Monsoon Biennial variability. WMO International Conference on Monsoon Forecasting from Days to Years, Delhi, India, March 2001. (Invited)

Chang, C.-P., Interdecadal variations of the ENSO – Monsoon relationship. 8th Scientific Assembly of International Association of Meteorology and Atmospheric Sciences, Innsbruck, Austria, July 2001. (Invited)

Chang, C.-P., Z. Wang, J. Ju and T. Li, 2001: Interactions of maritime continent winter monsoon, ENSO and Indian Ocean winds. The Third International Symposium on Asian Monsoon System, Okinawa, Japan, 11-14 December 2001.

Li, T., Y.-S. Zhang, B. Wang and C.-P. Chang, 2001: Monsoon-ENSO relationship during the decaying phase of ENSO. The Third International Symposium on Asian Monsoon System Okinawa, Japan, 11-14 December 2001.

DoD KEY TECHNOLOGY: Battlespace Environments, Modeling and Simulation

KEYWORDS: Monsoon, El Nino, ENSO, Climate Variations, Tropical Meteorology

STUDIES IN TROPICAL CYCLONE FORMATION

Kevin K. W. Cheung, Research Assistant Professor
Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Hong Kong Croucher Foundation and Office of Naval Research

OBJECTIVE: To understand the physics of tropical cyclone formation and improve the skill of tropical cyclone formation forecasts using numerical weather prediction models.

SUMMARY: The physics of tropical cyclone formation was studied using existing operational analyses and forecast fields, and with numerical simulations. In the former approach, large-scale conditions associated with tropical cyclone formations, particularly in the western North Pacific where many naval operations are carried out, were examined using analyses from operational centers such as the Naval Operational Global Atmospheric Prediction System (NOGAPS). Several quantities (e.g., vertical wind shear, mid-level moisture, and convective instability) were computed to measure the potential for tropical cyclone formation. These measures were also found to be useful in determining successful and failed

forecasts of NOGAPS. Current work consists of examining satellite imageries to extract characteristic behavior of cloud clusters during tropical cyclone formations.

In the second approach, numerical simulations using the National Center for Atmospheric Research/Pennsylvania State University mesoscale model (MM5) were performed on historical cases of tropical cyclones. Such numerical simulations have the advantage of a well-controlled environment, and the flexibility of performing sensitivity studies with different physical parameters. The objective of this part of study is to understand the role of mesoscale convective systems in tropical cyclone formations. This is a continuing project, and related publications are anticipated in the coming year.

PUBLICATION:

Cheung, K.K.W. and R.L. Elsberry, Tropical cyclone formations over the western North Pacific in the Navy Operational Global Atmospheric Prediction System Forecasts. *Weather and Forecasting* (submitted).

PRESENTATION:

Cheung, K.K.W., A modeling study of mesoscale convective vortices in relation to tropical cyclone formation. International Conference on Mesoscale Meteorology and Typhoon, Taipei, Taiwan, 26–28 September 2001.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Tropical Cyclone, Tropical Cyclogenesis, Numerical Modeling and Simulation

ATMOSPHERIC CORRECTIONS FOR GEODETIC QUALITY RADIO RANGING REAL DATA

Kenneth L. Davidson, Professor
Department of Meteorology
James R. Clynch, Research Professor
Department of Oceanography
Sponsor: Naval Postgraduate School Center for Reconnaissance Research

OBJECTIVE: Assess the role of atmospheric conditions, application of models and measurement capabilities in estimating tropospheric factors in global reconnaissance system performances.

SUMMARY: The primary goal was to establish limits on the noise (uncertainty) in radio frequency measurements that transit the atmosphere under the influence of temporal and spatial variations of the neutral atmosphere in space and time. The limitations at very low elevation angles for high altitude and space observation platforms were evaluated and quantified. Only the troposphere was considered, not the ionosphere. The results are applicable from about 500 MHz to 100 GHz. Atmospheric profile data from six world-wide locations were obtained in the form of balloon data. Two weeks of data were examined from Oakland, Vandenberg, San Diego, Sweden, Singapore and the Persian Gulf. Spatial variations were studied using the U.S. west coast sites. Ray tracing was used to examine the total delay and the bending for radio signals.

The primary quantity studied was the variation at each site. The natural variability will limit the utility of any model not driven with near real time data. At elevations below 2 degrees the effect were found to be significant. The variations were found up to 6 m in delay and 4 milliradians in bending below 0.6 deg. At 2 degrees the variations were 1.2 m and 0.8 mrad. Using data up to 600 km away (within the same air mass) reduced the variations above 1 degree by about 90 percent.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Propagation, Refraction

EVALUATION OF MBL PROFILE ESTIMATION AND ESTIMATING EM/EO FACTORS TO AID OPERATING FORCES

K. L. Davidson, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Command

OBJECTIVE: Validate/verify the Tactical Drop-sondes (TDrop) to meet requirements for accurate and tactically significant measurements of temperature, moisture, and pressure within the lower marine atmosphere and evaluate technical information transfer and application for refractivity effects on CGs.

SUMMARY: Evaluation was performed to evaluate the performance of the *in situ* application on other methods, i.e. Lidar, M_AERI, on-board sensor, for estimating refractivity profiles, continuously. Further, to explore properties of near-surface layer with kite-borne sensors for purpose of evaluate sensor goals. The Naval Postgraduate School (NPS) carried out analyses of application of its near-surface refractivity model for inclusion within the SMOOS(R) system. This model computes near-surface refractivity profiles and the evaporation duct height from environmental measurements provided by the shipboard SMOOS(R) measurement system. The model refractivity profiles can then be input into propagation assessment programs such as AREPS to predict near-surface radar performance in the current environment, including the probability of detection of specific threats. The NPS model has been incorporated into the AREPS and into SMOOS(R) system software developed by the Johns Hopkins University, Applied Physics Laboratory (JHU/APL). NPS and JHU/APL persons prepared a draft "rules of thumb" document for AGs and Radar Systems Controllers for "Guidance for METOC Personnel" to aid AN/SPY-1 radar operators in evaluating environmental conditions.

PUBLICATIONS:

Davidson, K.L. and P.A. Frederickson, Estimating Near-Surface Atmosphere Properties that Affect Weapons Systems, *NPS Research*, Featured Article, June 2001.

Frederickson, P.A., K.L. Davidson, J. Stapleton, D., Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Battlespace Atmospheric and Cloud Impact on Military Operations (BACIMO 2001) Conference, Fort Collins, CO, 10-12 July 2001. [Army Research Laboratory CD-ROM ARL-SR-01126, October 2001].

Frederickson, P.A., K.L. Davidson, J. Stapleton, D., Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Ship Based Defense Demonstration, IAFCSE Task – MPME Wallops 2000 Final Review, Naval Surface Warfare Center, Dahlgren, VA, 3 October 2001.

PRESENTATIONS:

Davidson, K.L. and P.A. Frederickson, METOC Sampling for Rf/EO Propagation Assessment. Modernizing METOC Support to the Surface (AEGIS) Warfighter, Pearl Harbor, HI, 22-23 February 2001.

Davidson, K.L., Effects and Estimation of Near-surface atmosphere effects on Rf/EO propagation/system performance. Simulation Validation Working Group (SVWG) Bi-Annual Meeting, Naval Research Laboratory, Washington, D.C., 26-28 June 2001.

THESES DIRECTED:

Sommer, W., "Difficulties in Identifying and Evaluating Surface-based and Evaporative Duct Impacts, Masters Thesis," Naval Postgraduate School, March 2001.

Eckardt, M., "Assessing the Effects of Model Error on Radar Inferred Evaporative Ducts," Masters Thesis, Naval Postgraduate School, March 2002.

Robinson, S., "Case Study Supporting the Usefulness of TEP as a Naval Mesoscale Weather Radar," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer

METOC DATA ACQUISITION (MORIAH/SMOOS(R))

K. L. Davidson, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Command

OBJECTIVE: Support acquisition strategy of a shipboard Meteorology and Oceanography parameter sensor system, MORIAH, by carrying out validation, verification and integration procedures. Prepare software documentation for acquisition and evaporation duct calculation.

SUMMARY: NPS evaluated and documented performance characteristics of MORIAH hardware and software for use in the complex METOC and electronic environment of a Navy warship. These were also done for MORIAH-like systems mounted on buoys deployed in coastal regimes in support of propagation tests. System performance evaluation was of characteristics of both the MORIAH hardware and acquisition and calculation/editing software. The algorithm for evaporation duct refractivity profiles using SMOOS(R)-type data was evaluated with buoy-based data collected in collection associated with the NSWC-DD directed Ship-Based Defense Demonstration, IAFCSE Task – MPME (Wallops 1998 & 2000), Sommers 2001, and Frederickson et al. 2001. The SMOOS(R) acceptable errors for all airflow and surface properties were used in an evaluation of the impact of the neutral profile assumptions within the Refractivity from Clutter (RFC) procedure, Eckardt 2002.

PUBLICATIONS:

Davidson, K.L. and P.A. Frederickson, Estimating Near-Surface Atmosphere Properties that Affect Weapons Systems. *NPS Research*, June 2001.

Frederickson, P.A., K.L. Davidson, F.K. Jones and D.L. Mabey, *SCI 2001 Sensor Technology Test; Preliminary METOC Data Atlas*, Naval Postgraduate School Technical Report, 19 December 2001, 83 pp.

Frederickson, P.A., K.L. Davidson, F.K. Jones and T. Neta, *NPS FLUX Buoy Data Report for the MUSE Deployment, August - September 2000*, Naval Postgraduate School Technical Report, 5 April 2001, 19 pp.

THESES DIRECTED:

Sommer, W., "Difficulties in Identifying and Evaluating Surface-based and Evaporative Duct Impacts," Masters Thesis, Naval Postgraduate School, March 2001.

Eckardt, M., "Assessing the Effects of Model Error on Radar Inferred Evaporative Ducts," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer

REFRACTIVITY PROFILE COLLECTION DURING RED

K. L. Davidson, Professor
Department of Meterology
Sponsor: Naval Research Laboratory

OBJECTIVE: Characterize the low altitude refractivity conditions (particularly the height and strength of possible surface based ducts) that affect RF propagation along the FLIP-based Rf and EO propagation paths during the Roughness and Evaporation Duct experiment.

SUMMARY: Naval Postgraduate School (NPS) obtained launched rawinsondes and kite-borne sonde profiles from a small boat during the RED experiment conducted on the windward shore of Oahu in August-September 2001. The profiles were obtained during this experiment to provide information for interpreting radio frequency (RF) propagation measurements along a 26 km path between the *R/V FLIP*, moored 10 km off the north shore of Oahu, and a shore receiver station on Mokapu Peninsula and optical propagation measurements obtained along a 10 km path between *FLIP* and the north shore of Oahu.

The NPS measurement platform was the small vessel *Wailoa*. NPS obtained 190 individual near-surface (up to ~100 meters) kite-borne sonde profiles and 20 upper-air balloon-sonde profiles on eight different days during the experiment. Mean meteorological data were also obtained by Scripps-UCSD on the *Wailoa* during these eight days.

PRESENTATIONS:

Guest, P.S., K.L. Davidson, P.A. Frederickson and D.L. Mabey, Using instrumented kites to quantify atmospheric conditions during the RED experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

THESES DIRECTED:

Mabey, D., "Variability of Refractivity in the Surface Layer Over the Sea," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer, Optical Transmission, Rf Transmission

SCALING NEAR-SURFACE ATMOSPHERIC AND SURFACE WAVE INFLUENCES ON RADAR PROPAGATION OVER THE SEA (RED EXPERIMENT ANALYSES)

K. L. Davidson, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: Improve models for describing near horizon Rf/EO propagation over the ocean through evaluation of the Monin-Obukhov surface-layer scaling for near surface turbulence and refractivity gradients over ocean waves and surface roughness parameterizations.

SUMMARY: Analyses and interpretations were performed on measurements of near-surface refractive gradients, turbulent intensity, and surface wave data obtained during NPS flux buoy deployments from coordinated propagation experiments. These data were from combined collections of *in situ* meteorological and radar-frequency propagation data conducted off Wallops Island, VA during the spring (March through May) of 1998 and 2000. The EO data were from combined collections of *in situ* and propagation (EO) in San Diego Bay, CA and Duck NC from 1996 through 1998. Buoy data and EM and EO propagation data were also obtained during the RED experiment conducted in the late summer of 2001. Collaborative analyses/interpretations during preceding field experiment years emphasized mean airflow properties. Our own interpretations addressed the use of current bulk methods for estimating optical turbulence (C_n^2) and

scaling parameters (T_*, q_*, and u_*). Waves influences have been addressed to qualitatively identify the influence. Existing results demonstrate that current models perform well in unstable conditions but clearly not in stable conditions.

PUBLICATIONS:

Mahrt, L., D. Vickers, J. Sun, T. Crawford, G. Crescenti and P. Frederickson, Surface stress in offshore flow and quasi-frictional decoupling. *Journal of Geophysical Research (Atmospheres),* Vol. 106, pp. 20629-20639, 2001.

Jensen, D.R., S.G. Gathman, C.R. Zeisse, C.P. McGrath, G. de Leeuw, H.M. Smith, P.A. Frederickson and K.L. Davidson, Electrooptical propagation assessment in coastal environments (EOPACE) summary and accomplishments. *Optical Engineering*, Vol.40, pp. 1486-1498, 2001.

Frederickson, P.A. and K.L. Davidson, Observational buoy studies of coastal air-sea fluxes. *Journal of Climate*, January 2002.

Zeisse, C.R., A.E. Barrios, S.M. Doss-Hammel, G. de Leeuw, M. Moerman, A.N. de Jong, P.A. Frederickson and K.L. Davidson, Low altitude infared propagation over the ocean, *Applied Optics*, submitted 2001.

PRESENTATIONS:

Davidson, K.L. and P.A. Frederickson, Influence of ocean waves on near-surface turbulence and refraction profiles: scaling over waves. Abstracts of the National Radio Science Meeting (URSI), Boulder, CO, 10-13 January 2001.

Davidson, K.L. and P.A. Frederickson, Mid-Path near-surface atmospheric properties in the roughness and evaporation duct (RED) experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

Guest, P.S., K.L. Davidson, P.A. Frederickson and D.L. Mabey, Using instrumented kites to quantify atmospheric conditions during the RED experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

Davidson, K.L. and P.A. Frederickson, Near-surface meteorology descriptions and radar propagation. South Dakota School of Mines and Technology, 31 January 2002.

Davidson, K.L., P.A. Frederickson and D.L. Mabey, Mid-path near-surface atmospheric properties in the roughness and evaporation duct (RED) experiment, RED Experiment Data Workshop, San Diego, CA, 5-6 February 2002.

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DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer, Optical Transmission, Rf Transmission, EM/EO Propagation

DEVELOPMENT AND VALIDATION OF MULTIPLE-SATELLITE DATA SETS FOR GLOBAL AEROSOL RADIATIVE FORCING

Philip A. Durkee, Professor
Department of Meteorology
Sponsor: National Aeronautics and Space Administration

OBJECTIVES: This project supported development of multiple-satellite aerosol optical depth retrieval methods for global-scale analysis of radiative forcing. Validation methods included data and experience gained in participation in numerous recent field programs.

SUMMARY: This was the third year of this three-year project. Extensive validation activities have been conducted using the ACE-2 and TARFOX data sets:

- Comparisons of surface, ship-board, and aircraft sunphotometers with satellite retrievals (TARFOX, ACE-2, Aerosols99/INDOEX).
- Tests of aerosol model assumptions against *in situ* aircraft measurements of aerosol properties such size distribution, composition, and resulting radiative properties.
- Validation within the context of complete column closure studies is continuing.
- Tests of the effects of sunglint and cloud screening techniques.

Regional analysis of optical depth including wavelength variation and variation statistics was conducted for the four recent aerosol experiments (ACE-1, TARFOX, ACE-2, and Aerosols99/INDOEX). Development of retrievals from combined NOAA AVHRR and GOES are in progress. Validation of these techniques includes observations from TARFOX, EOPACE, and recent observations off the U.S. West Coast.

Aerosol optical depth retrieval using combinations of AVHRR and GOES imagery was studied using data from the western Atlantic Ocean. Analysis demonstrated the need for specialized scattering phase functions when desert dust was the primary aerosol type.

PUBLICATIONS:

Durkee, P.A., K.E. Nielsen, P.J. Smith, P.B. Russell, B. Schmid, J.M. Livingston, B.N. Holben, C. Tomasi, V. Vitale, D. Collins, R.C. Flagan, J.H. Seinfeld, K.J. Noone, E. Öström, S. Gassò, D. Hegg, L.M. Russell, T.S. Bates and P.K. Quinn, 2000: Regional aerosol optical depth characteristics from satellite observations: ACE-1, TARFOX and ACE-2 results. *Tellus*, 52B, 484-497.

Gassò, S., D.A. Hegg, D.S. Covert, D. Collins, K.J. Noone, E. Öström, B. Schmid, P.B. Russell, J.M. Livingston, P.A. Durkee and H. Jonsson, 2000: Influence of humidity on the aerosol scattering coefficient and its effect on the upwelling radiance during ACE2. *Tellus*, 52B, 546-567.

Schmid, B., J.M. Livingston, P.B. Russell, P.A. Durkee, H.H. Jonsson, D.R. Collins, R.C. Flagan, J.H. Seinfeld, S. Gasso, D.A. Hegg, E. Ostrom, K.J. Noone, E.J. Welton, K.J. Voss, H.R. Gordon, P. Formenti and M.O. Andreae, 2000: Clear-sky closure studies of lower tropospheric aerosol and water vapor during ACE-2 using airborne sunphotometer, airborne *in-situ*, space-borne and ground based measurements. *Tellus*, 52B, 568-593.

Livingston, J.M., V.N. Kapustin, B.Schmid, P.B. Russell, P.K. Quinn, T.S. Bates, P.A. Durkee, P.J. Smith, V. Freudenthaler, M. Wiegner, D.S. Covert, S. Gasso, D. Hegg, D.R. Collins, R.C. Flagan, J.H. Seinfeld, V. Vitale and C. Tomasi, 2000: Shipboard sunphotometer measurements of aerosol optical depth spectra and columnar water vapor during ACE-2 and comparison with selected land, ship, aircraft, and satellite measurements. *Tellus*, 52B, 594-619.

Welton, E.J., K.J. Voss, H.R. Gordon, H. Maring, A. Smirnov, B. Holben, B. Schmid, J.M. Livingston, P.B. Russell, P.A. Durkee, P. Formenti and M.O. Andrea, 2000: Ground-based lidar measurements of aerosols during ACE-2: instrument description, results, and comparisons with other ground-based and airborne measurements. *Tellus*, 52B, 636-651.

Johnson, D.W., S. Osborne, R. Wood, K. Suhre, R. Johnson, S. Businger, P.K. Quinn, A. Wiedensohler, P.A. Durkee, L.M. Russell, M.O. Andreae, C. O'Dowd, K.J. Noone, B. Bandy, J. Rudolph and S.

Rapsomanikis, 2000: An overview of the Lagrangian experiments undertaken during the North Atlantic Regional Aerosol Characterization Experiment (ACE-2). *Tellus*, 52B, 290-320.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Satellite, Remote Sensing, Aerosol Processes, Atmospheric Radiation

HYMSIC PROJECT

Philip A. Durkee, Professor
Department of Meteorology
Sponsor: Secretary of the Air Force

OBJECTIVE: Develop atmospheric and oceanic analysis using satellite-measured radiance.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Satellite, Remote Sensing, Clouds, Aerosols

METOC DATA ASSIMILATION AND MODELING

Philip A. Durkee, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: Develop atmospheric and oceanic analysis using satellite-measured radiance.

SUMMARY: This project produced verification and validation of the Satellite Marine-layer/Evaporation Duct Height (SMDH) technique under development by NAWC Point Mugu, California. The technique provides an estimate of the cloud-top height of stratocumulus clouds in the marine boundary layer for the area viewed by a polar orbiting weather satellite. The top of the marine boundary layer is the optimum coupling height for elevated ducts. Knowledge of the elevated duct height over the tactical battlespace is quite important. The SMDH technique is one component of a potential shipboard operational system to provide estimates of elevated duct height. The SMDH technique is verified using NOAA AVHRR satellite data and coincident rawinsonde or aircraft measurements from the 1987 FIRE and 1994 MAST data sets.

PUBLICATIONS:

Jordan, M.S. and P.A. Durkee, *Verification and Validation of the Satellite Marine-layer/Elevated Duct Height (SMDH) Technique*, Naval Postgraduate School Technical Report, NPS-MR-01-001, 2001, 26pp.

THESIS DIRECTED:

McBride, M.B., III, "Estimation of Stratocumulus-Topped Boundary Layer Depth Using Sea Surface and Remotely Sensed Cloud-Top Temperatures," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Satellite, Remote Sensing, Clouds

SUPPORT FOR USWRP ASSOCIATE LEAD SCIENTIST

Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: This project is for Professor Elsberry to serve as the Associate Lead Scientist (Hurricane Landfall) for the U.S. Weather Research Program, which is sponsored by the Office of Naval Research. Professor Elsberry will carry out the duties of the Associate Lead Scientist as described in the terms of reference dated January 1999.

SUMMARY: The first task during 2001 was the arrangement of a day-long session with a poster session on tropical cyclone-related precipitation as part of the Symposium on Precipitation Extremes at the national meeting of the American Meteorological Society (AMS). In addition to the conference paper (Elsberry 2001a), a meeting summary (Elsberry 2001c) is to be published in the *Bulletin AMS*. A summary of the U. S. Weather Research Program plans was presented at an International conference (Elsberry 2001d).

The second task was to lead the Team that established the Joint Hurricane Testbed (JHT) at the National Hurricane Center. The JHT was designed following an earlier concept called the Hurricane Operational Transition (HOT) Center (Elsberry 2001f). Based on a limited call for proposals, nine projects were funded to move research to operations more rapidly and efficiently.

A journal article (Hirschberg et al. 2001) based on an earlier USWRP project was published. Two multiply-authored articles (Nagata et al. 2001a,b) related to testing various mesoscale models for a case of explosive development of a tropical cyclone were also published. A book chapter (Elsberry 2001b) describing the improvements in track forecast guidance also appeared in 2001.

PUBLICATIONS:

Elsberry, R.L., 2001a: Hurricane-related precipitation cannot be predicted on useful time intervals – only quantitative precipitation estimation makes sense. *Preprints, Symposium on Precipitation Extremes*, American Meteorology Society, Albuquerque, NM, 14-18 January, 381-385.

Elsberry, R.L., 2001b: Extratropical transitions of tropical cyclones – Pathway to operations. 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January – 1 February 2001.

Elsberry R.L., 2001c: Proposed Hurricane Operational Transition (HOT) center. Presentation, Interdepartmental Hurricane Conference, Orlando, FL, 6 March 2001.

Elsberry, R.L., 2001d: USWRP hurricane landfall precipitation analysis and forecasting. Preprints, International Conference on Mesoscale Meteorology and Typhoons in East Asia, Taipei, Taiwan, 26-28 September.

Hirschberg, P.A., P.C. Shafran, R.L. Elsberry and E. A. Ritchie, 2001: An observing system experiment with the west coast picket fence. *Monthly Weather Review*, **129**, 2585-2599.

Nagata, M. and 20 co-authors, 2001: Third COMPARE Workshop: A model intercomparison experiment of tropical cyclone intensity and track prediction. *Bulletin of American Meteorology Society*, **82**, 2007-2020.

Nagata, M. and 20 co-authors, 2001: A mesoscale model intercomparison: A case of explosive development of a tropical cyclone (COMPARE III). *Journal Meteorological Society Japan*, **79**, 999-1033.

PRESENTATIONS:

Elsberry, R.L., 2001e: Extratropical transitions of tropical cyclones – Pathway to operations. 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January–1 February 2001.

Elsberry R.L., 2001f: Proposed Hurricane Operational Transition (HOT) center. Interdepartmental Hurricane Conference, Orlando, FL, 6 March 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: U.S. Weather Research Program, Hurricane Landfall, Tropical Cyclones

TRANSITION OF DYNAMICAL MODEL TRACK PREDICTION EVALUATION SYSTEM

Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Agency

OBJECTIVE: This proposal is to transition to the Tropical Prediction Center/National Hurricane Center a dynamical model evaluation expert system. The primary effort during the first year was to convert the code and conduct a beta test of the system. The objective during the second year is to produce a version suitable for operational testing.

SUMMARY: A limited conversion of the Systematic Approach Forecasting Aid (SAFA) code for the western North Pacific was accomplished for a beta test of tropical cyclone tracks forecasting in the Atlantic. This version of the code continued to use Navy sources for the dynamical model tracks and fields necessary to run the new code called Dynamical Model Evaluation System (DYMES). These fields were then transferred to the National Hurricane Center in Miami where LCDR Laura Salvador (Navy Liaison) tested the converted code on a workstation provided by this project. Application of DYMES at the Naval Postgraduate School was accomplished by Mark Boothe in a simulated real-time mode. Although a number of communication problems occurred, the first-year objectives were accomplished.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Tropical Cyclone Track Prediction, Expert System

USING THE SHEBA FLUX DATA TO IMPROVE REGIONAL AND GLOBAL CLIMATE MODELS

Peter Guest, Research Associate Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVES: This is a collaborative effort to use the atmospheric surface layer data collected during the Surface Heat Budget of the Arctic (SHEBA) field program to develop ice-atmosphere exchange algorithms for local, regional and global model ice-atmosphere model of the Arctic.

SUMMARY: This continues an analysis of data collected during a field program that was performed from September 1997 to September 1998. The data set obtained represents the most comprehensive information on surface-layer properties ever obtained in the central Arctic. The project involves analysis of factors affecting the surface heat and momentum fluxes, including snow drifting, melting of the ice surface, radiation and cloud effects and the effects of nearby leads. These results are being incorporated into various models that simulate Arctic air-ice-sea interactions and their effects on regional and global climate.

PUBLICATIONS:

Andreas, T.L., C.W. Fairall, O.P.G. Persson and P.S. Guest, 2002: Probability distributions for the inner scale and the refractive index structure parameter and their implications for flux averaging. *Journal of Geophysical Research*, (in press).

Andreas, E.L., P.S. Guest, O.P.G. Persson, C.W. Fairall, T.W. Horst, R.E. Moritz and S.R. Semmer, 2002: Near-surface water vapor over polar sea ice is always near saturation, *Journal of Geophysical Research-Oceans*, (in press).

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Intrieri, J.M., C.W. Fairall, M.D. Shupe, O.P.G. Persson, E.L. Andreas, P.S. Guest and R.E. Moritz, 2002: An annual cycle of Arctic surface cloud forcing at SHEBA. *Journal of Geophysical Research*, (in press).

Persson, P.O.G., C.W. Fairall, E.L. Andreas and P.S. Guest, 2002: Measurements near the Atmospheric Surface Flux Group tower at SHEBA: Near-surface conditions and surface energy budget, *Journal of Geophysical Research-Oceans*, (in press).

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PRESENTATIONS:

Andreas, E.L., P.S. Guest, O.P.G. Persson, C.W. Fairall, T.W. Horst and R.E. Moritz, 2001: Relative humidity measurements near saturation at temperatures well below 0°C. Preprint volume, 11th Symposium on Meteorological Observations and Instrumentation of the American Meteorological Society, Albuquerque, NM, 14-18 January 2001, 159-164. (Program in *Bulletin American Meteorology Society*, **81**, 2848-2855.)

Andreas, E.L., C.W. Fairall, P.S. Guest and O.P.G. Persson, 2001: The air-ice drag coefficient for a year over Arctic sea ice. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Fairall, C.W., J.M. Intrieri, M. Shupe, P. Guest, E.L. Andreas and O.P.G. Persson, 2001: Cloud forcing of turbulent and radiative energy budgets on the Arctic ice cap: one year of data from the SHEBA experiment (invited talk). Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Guest, Peter S., O.P.G. Persson, E.L. Andreas and C.W. Fairall, 2001: What is the role of the sensible hear flux on the surface heat budget of the multi-year sea ice? (invited talk). Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Guest, P.S., A. Schweiger, T. Beesley, E. Andreas, C. Fairall and P.O. Persson, 2002: Atmospheric Forcing in PIPS 3.0, PIPS 3.0. Meeting. Fleet Numerical Oceanography and Meteorology Center, Monterey, CA, 23-24 January 2002.

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DoD KEY TECHNOLOGY AREAS: Other (Meteorology)

KEYWORDS: Polar Meteorology, Air-Sea-Ice Interactions, Surface Fluxes

NUMERICAL HINDCASTS OF THE CALIFORNIA CURRENT

Robert L. Haney, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The broad objective of this research is to support the Navy in the development of a reliable ocean modeling and prediction capability for the coastal oceans.

SUMMARY: During FY01 studies were completed in the California Current, in the Alboran Sea, and on the variability of the global thermohaline circulation. In the California Current a new explanation was offered for the offshore propagation of eddy kinetic energy recently observed by satellite data (Haney et al. 2001) and the three dimensional circulation and vertical velocity in several coastal jets and filaments observed in the ONR Coastal Transition Zone (CTZ) program (Haney and Hale 2001) were diagnosed and observed. In collaboration with Spanish colleagues, we identified several new eddy features in the Alboran Sea observed by Synthetic Aperture Radar (Font et al. 2002). Finally, in collaboration with a Spanish doctoral student and other colleagues, it was shown that a new nonlinear mechanism, stochastic resonance, makes the thermohaline circulation more likely to undergo significant fluctuations in response to variations in atmospheric forcing (Velez-Belchi et al. 2001).

PUBLICATIONS:

Haney, R.L., R.A. Hale and D.E. Dietrich, 2001: Offshore propagation of eddy kinetic energy in the California Current. *Journal of Geophysical Research,* **106**, 11709-11717.

Haney, R.L. and R.A. Hale, 2001: The use of digital filter initialization to diagnose the mesoscale circulation and vertical motion in the California coastal transition zone. *Journal of Marine Systems*, **29**, 335-363.

Velez-Belchi, P., A. Alvarez, P. Colet, J. Tintore and R.L. Haney, 2001. Stochastic resonance in the thermohaline circulation. *Geophysical Research Letters,* **28**, 2053-2056.

Font, J., S. Rousseau, B. Shirasago, E. Garcia-Gorriz and R.L. Haney, 2002: Mesoscale variability in the Alboran Sea: Synthetic Aperture Radar imaging of frontal eddies. *Journal of Geophysical Rsearch,* **107**, in press.

PRESENTATIONS:

Haney, R.L., R.A. Hale and D.E. Dietrich, 2001: Offshore propagation of eddy kinetic energy in the California Current. 13th AMS Conference on Atmospheric and Oceanic Fluid Dynamics, Breckenridge, CO, 4-8 June 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Coastal Transition Zone, Global Thermohaline Circulation

EVOLUTION OF TROPICAL CYCLONE CHARACTERISTICS

Patrick A. Harr, Research Associate Professor
Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: Tropical cyclone frequency, motion, and structure characteristics depend on a variety of environmental and internal factors. The primary objectives of this research are to identify these factors and determine how each impacts tropical cyclone characteristics.

SUMMARY: Tropical cyclone activity/inactivity may be related to mechanisms that act over a variety of space and time scales. It is hypothesized that the mechanisms responsible for clustering of tropical cyclone activity can be put into a framework of interactions between several modes of circulation variability. A wavelet analysis was used to define the dominant modes of low-level circulation and outgoing longwave radiation (OLR) variability over the western North Pacific in a time-frequency reference. Partitions have been identified to represent an intraseasonal mode (30-90 days), a western North Pacific monsoon trough mode (10-25 days), and a synoptic mode (2-8 days). A singular value decomposition (SVD) analysis was used to describe the primary patterns of large-scale variability associated with the covariance between circulation features and OLR identified with predominant peaks in spectral power. Based on circulation indices from data filtered for each frequency range, a cross-wavelet analysis defined periods of significant covariability between the frequency ranges. New circulation and OLR modes are defined based on separation of periods of significant interactions between frequency bands from periods when there are no interactions. The addition of these conditioned modes to the individual modes defined above increases the amount of explained variability in tropical cyclone activity.

The study of the extratropical transition of western North Pacific tropical cyclones (TCs) addressed the re-intensification stage during which the TC remnants develop as an extratropical cyclone. The relative contributions from midlatitude circulations and the decaying tropical cyclone were assessed with numerical simulations by removing the tropical cyclone remnants from the model initial conditions or displacing the remnants relative to the midlatitude circulation. Re-intensification is favored when the upper-level TC outflow enhances the equatorward entrance region of a downstream jet streak, and when the TC remnant circulation interacts with the lower-tropospheric baroclinic zone. Thus the interaction is not a static process, but a dynamic process in which both the TC and midlatitude circulation have a contribution.

An algorithm has been developed to detect and track in dynamical model fields those circulations that have become, or are forecast to become, tropical cyclones. Additionally, specific environmental conditions in the model analysis and forecast fields are attached to the tracked circulation. Threshold values of important environmental parameters associated with failed and successful model predictions of tropical cyclone formation are identified at each forecast range.

PUBLICATIONS:

Chang, C.–P., P.A. Harr and J. Ju, 2001: Possible roles of Atlantic circulations on the weakening Indian monsoon rainfall-ENSO relationship. *Journal of Climate*, **14**, 2376-2380.

Klein, P.M., P.A. Harr and R.L. Elsberry, 2001: Extratropical transition of western North Pacific tropical cyclones: Midlatitude and tropical cyclone contributions to re-intensification. *Monthly Weather Review* accepted pending minor revisions.

Jones, S.C., P.A. Harr, J. Abraham, L.F. Bosart, P.J Bowyer, B.N. Hanstrum, M.R. Sinclair, R.K. Smith and C. Thorncroft, 2001: The extratropical transition of tropical cyclones: Forecast challenges, current understanding and future directions. *Weather and Forecasting*, In revision.

PRESENTATIONS:

Harr, P.A. and R.L. Elsberry, 2001: An overview of heavy precipitation associated with the extratropical transition of tropical cyclones. *Preprints, Symposium on Precipitation Extremes:* Prediction, Impacts and Responses. American Meteorology Society, Boston, MA, 02108, 288-292.

Harr, P.A. and R.L. Elsberry, 2002: Prediction of intraseasonal variability in tropical cyclone activity over the western North Pacific Ocean. 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 29 April-3 May 2002.

Doric, T., P.A. Harr and R.L. Elsberry, 2002: Assessment of the potential for prediction of tropical cyclone formation in the Navy global model. 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 29 April-3 May 2002.

Klein, P.M., P.A. Harr and R.L. Elsberry, 2002: Extratropical transition of western North Pacific tropical cyclones: Midlatitude and tropical cyclone contributions to re-intensification. 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 29 April-3 May 2002.

DoD TECHNOLOGY AREA: Environmental Quality, Modeling and Simulation

KEYWORDS: Tropical Cyclones, Midlatitude Cyclones, Numerical Weather Prediction, Extratropical Transition

GLOBEC - NORTHEAST PACIFIC CLIMATE CHANGE MECHANISMS

Tom Murphree, Senior Lecturer
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Administration

OBJECTIVES: This project is designed to analyze long term weather and climate variations in the North Pacific – North American atmosphere and ocean, and the mechanisms that produce these variations.

SUMMARY: This project is part of the U.S. GLOBEC research program, funded by the National Science Foundation and the National Oceanic and Atmospheric Administration (NOAA). These projects are being conducted in collaboration with researchers in the Department of Oceanography at the Naval Postgraduate School (NPS) and at the Pacific Fisheries Environmental Laboratory (PFEL) of NOAA in Pacific Grove, CA. Our goal is to develop a better understanding of the intraseasonal to decadal variations of the atmosphere and ocean in the North Pacific – North American (NPNA) region. The work emphasizes the identification and description of the mechanisms that govern these variations (e.g., teleconnections form remote regions and their impacts on surface wind stress and moisture transports). This research involves dynamical analyses of observed, analyzed, and modeled atmospheric and oceanic fields. During 2001, the focus was on: (1) additional development and application of the Northern Oscillation Index (NOI) and other observational and model products; (2) diagnostic analyses of interannual to decadal variations of the atmosphere and upper ocean; (3) analyses of the simulation of these variations by a global ocean general circulation model; and (4) identification of the major atmospheric and oceanic mechanisms that link the NPNA region to southern and eastern Asia and the tropical Pacific. Some specific aspects of this work are described below.

Monthly updated climatologic and retrospective data were maintained for use in the project and by the GLOBEC research community. A current focus is developing data products from subsurface databases. Subsurface ocean variations may be: (a) large and persistent; difficult to infer from surface variations; and (c) a significant factor in the development of subsequent surface variations. In addition, the output from global ocean general circulation models are compared to observed fields, and developing data products based on the model output.

Decadal fluctuations in global climate are major climate events that can be identified by a number of climate indices, including the Northern Oscillation Index (NOI), and upper ocean temperature anomalies in the NPNA region. During the negative NOI phase, for example, NPNA temperatures are anomalously warm and NPNA surface wind stress is anomalously anticyclonic. The warm phase of this pattern has dominated since 1976. However, analyses indicate a regime shift toward the negative NPNA anomaly phase may have occurred in mid-1998. Results also indicate that decadal anomaly patterns are dynamically similar to those on interannual (e.g., El Niño/La Niña), seasonal, and intraseasonal (e.g., weekly to monthly variations of tropical and monsoon convection) scales.

A central question in the work is the degree to which variations in the NPNA region are triggered by vertical fluxes (e.g., those associated with *in situ* wind stress curl) versus lateral transports (e.g., those associated with atmospheric teleconnections, ocean planetary waves). Climatologic and anomalous variations in historical data sets and model output are currently being analyzed to quantify the roles of each. Early results indicate long-term variability in the NPNA region is a complex signal composed of both sources of forcing, but with wind stress curl and consequent geostrophic advections being especially important for large scale variations occurring on intraseasonal and longer time scales.

One hypotheses is that atmospheric and oceanic teleconnections explain much of the climate variability in the NPNA region. Recent research has identified specific locations – the central and western tropical Pacific, east Asia, and the Asian Arctic – where atmospheric teleconnections originate that

commonly affect the NPNA region on intraseasonal to decadal scales. Ongoing work is seeking to determine the relative role of each source, climatologically and for individual climate events, and the mechanisms by which atmospheric anomalies influence the upper ocean.

It is also hypothesized that the seasonal evolution of ocean conditions, and the atmospheric factors that force them, may be an analog to the development of interannual (e.g., El Niño/La Niña) and decadal (e.g., regime shift) ocean anomalies. Current focus is on analyses on understanding the seasonal response of the NPNA region to atmospheric forcing, and relating this relationship to anomalies on interannual and longer time scales, based on historical data and model output.

PUBLICATIONS:

Murphree, T., L. Feinberg, F. Schwing and R. Smith. 2001. Decadal Events in the Northeast Pacific. *Report of the U.S. GLOBEC Northeast Pacific California Current Scientific Investigators Meeting*. NEP GLOBEC Office, Corvallis, OR..

Schwing, F.B., T. Murphree and P.M. Green. 2002. The Northern Oscillation Index (NOI): a new climate index for the northeast Pacific. *Progress in Oceanography*, in press.

Schwing, F.B., T. Murphree, L. deWitt and P.M. Green. 2002. The evolution of oceanic and atmospheric anomalies in the northeast Pacific during the El Niño and La Niña events of 1995-2001. *Progress in Oceanography*, **53**, 115-139.

PRESENTATIONS:

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Murphree, T., B. Ford, F. Schwing and P. Green. Teleconnections from southeast Asia and the western tropical Pacific: their role in north Pacific and North American climatic variations. Pacific Climate Workshop, Pacific Grove, CA, March 2001.

Murphree, T. West coast weather and climate: the tropical connections. American Meteorological Society Chapter Meeting, Monterey, CA, December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Environmental Processes, Environmental Monitoring, Environmental Modeling)

KEYWORDS: Atmospheric and Oceanic Variations, El Niño, GLOBEC, La Niña, Long Term Weather, North Pacific, Teleconnections, Weather and Climate Systems

CENTRAL CALIFORNIA MESONET FOR USE IN LAPS AND LOCAL MESOSCALE MODELING

Wendell A. Nuss, Associate Professor
Department of Meteorology
Sponsor: National Weather Service

OBJECTIVE: The objective of this project is to develop a mesoscale observing network from existing sources and utilize these data in the Local Analysis and Prediction System (LAPS) at San Jose State University and real-time MM5 forecasts at the Naval Postgraduate School. The data will also be used to conduct model verifications and mesoscale circulation studies.

SUMMARY: Data from a variety of observing networks are being gathered by NPS to develop a California mesoscale observing network (mesonet). Presently observations from the California Department of Forestry, National Weather Service, and various NPS run stations are being collected in real-time with stations from local air pollution districts and the California Irrigation Management Service being collected once per day. These observations a being shared with San Jose State University and the National Weather Service as well as being used to produce a local mesoscale wind analysis that is displayed on the web (http://www.weather.nps.navy.mil/wx/latest_mbay.gif). The mesonet data is being utilized to feed into the real-time mesoscale model forecasts done by NPS. Additional observations from the California Department of Water Resources were added to the mesonet. The data have also been reformatted into a standard form for easier distribution and use.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Coastal Meteorology, Mesoscale Modeling, Regional Forecasting

PRACTICAL LIMITS TO ATMOSPHERIC MESOSCALE PREDICTABILITY

Wendell A. Nuss, Associate Professor
Douglas K. Miller, Research Assistant Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The objectives of this research are to determine the ability to numerically predict mesoscale coastal structures in a variety of synoptic scale situations and demonstrate for given small-scale structures the time ranges under which they might be considered predictable. The answer is probably dependent on the data assimilation system and one objective is to determine this sensitivity.

SUMMARY: A diagnostic study of the causes of differences in terrain enhanced precipitation due to slight changes in the topographic orientation has been completed and reveals that the precipitation is highly sensitive to the amplitude of moist mountain waves induced by the flow across the topography. When the flow more directly impinged upon the topography, higher amplitude mountain waves were observed. This resulted in more drying in the lee of the topography and a strong humidity gradient that forced greater precipitation in the model. When the flow was more parallel to the topography, a weaker flow across the mountain occurred and lower amplitude mountain waves. This resulted in more uniform moisture and less precipitation. The differences in cross-mountain flow were found to be the result of increased frontogenesis for the flow oriented more cross-mountain. The increased frontogenesis developed due to feedback during the preceding 12 hours. This sensitivity highlights the limits of mesoscale predictability for landfalling frontal systems.

The results from Kuypers (2000) suggested that the structure of the observational sample could substantially impact on the growth of forecast error. Consequently, experiments to test whether a sampling strategy optimized for the data assimilation system would consistently produce reduced forecast error was designed and carried out during the past year. The results of designing this sampling strategy revealed that extensive, scattered observations were necessary to define a wide variety of atmospheric structures. This highlighted the need to completely sample a wide range of wavelengths in the atmospheric structure. After extracting this optimal sample, a similar number of random observations were extracted and both sets were used to assimilate into the model to compare their impact on short-term forecasts. The results show that the optimal sampling consistently reduced error compared to random sampling. This suggests that the structure of a observational sample is very important to reduce error. While the targeting was based on defining the basic thermal structure of the forecast atmosphere, optimally sampling dynamically based sensitivity patterns from adjoint sensitivity or ensemble methods could also be done. This might improve the error reduction even more.

PUBLICATIONS:

Nuss, W.A. and D.K. Miller, 2001: Mesoscale Predictability under Various Synoptic Regimes. *Nonlinear Processes in Goephysics*, 25 .

PRESENTATIONS:

Nuss, W.A. and D.K. Miller, 2001: A Comparison of Mesoscale Forecast Accuracy using Random and a Simplified Targeting Approach. Preprints, Ninth Conference on Mesoscale Processes, Ft. Lauderdale, FL, 30 July–2 August 2001.

Nuss, W.A., 2001: Relationship between Synoptic Scale and Mesoscale Forecast Errors. PACJET Workshop, Monterey, CA, 24-26October 2001.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Data Assimilation, Predictability, Regional Forecasting

EASTERN PACIFIC OCEAN LAND-FALLING JETS STUDIES

Douglas Miller, Research Assistant Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Agency

OBJECTIVE: Assist in developing techniques for synthesizing data using a MacIntosh laptop computer onboard the P-3 and transmitting text and images via a new airborne satellite communications link. Test these new tools (laptop, software for graphics manipulation, and sending of messages via satcom) on flights during the "shakedown phase" of PACJET-2001 in January 2001.

The primary task under this contract is to serve as the on-board data synthesis focal point and prototype forecast product generator on all upcoming PACJET flights in 2001. The specific work requirements will be to sort through, as part of a team, a large number and variety of airborne observations gathered in a storm and to create useful image or text files which can relate important aspects of the storm structure to forecasters on the ground, given the limitations of communications bandwidth between the P-3 and the ground.

Prepare a brief written summary of his experience in that position, including examples of successes and problems, and recommendations for improving the performance during the proposed PACJET-2002 deployment.

SUMMARY: The 2000-2001 field phase of PACJET was successfully executed with each of the objectives completed by 1 April 2001. Changes have been implemented for upcoming field phases based on the experiences and recommendations made from observations during the 2000-2001 PACJET field phase.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: PACJET, Land-Falling Jets

ANALYSES OF AIRCRAFT MEASUREMENTS OF BOUNDARY LAYERS AND STRATUS CLOUDS IN THE ARCTIC

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: National Aeronautics and Space Administration - Langley

OBJECTIVE: The objective of this project is to understand the inhomogeneity in the Arctic boundary layer as a result of low-level clouds and the ice surface features such as leads. The goal is to understand the magnitude and variation of surface turbulent fluxes in the total energy budget of the Arctic climate system. The study is part of the effort of FIRE-III/SHEBA.

SUMMARY: Aircraft measurements on boundary layer turbulence structure were made by the NCAR C-130 during the Beaufort Arctic Storms Experiment (BASE) in 1994 and during the Surface Heat Budget of the Arctic (SHEBA) experiment in 1998. Data from one flight during the BASE experiment have been analyzed to study the boundary layer inhomogeneity introduced by the presence of low-level clouds and the fractional cloud cover. It was found that the boundary layer thermodynamics were largely determined by the cloud-top height, since the presence of cloud generally resulted in one or two mixed layers below the cloud top. The two-mixed layer structure in some of the soundings is the result of multiple cloud layers, which is different from the decoupled boundary layers in the subtropical marine boundary layers. In addition, the presence of low-level cloud significantly increased the intensity of boundary layer turbulence. However, significant increase in the magnitude of surface flux in cloudy region compared to the clear region was not observed. Further study indicated that the small flux is caused by the small temperature or moisture perturbation. The turbulence spectra in the clear and cloudy regions indicated that the cloud layer alters the turbulence spectra significantly. Meanwhile, we have performed extensive data analysis for the C-130 measurements made during SHEBA to study the variation of boundary layer stratification and turbulence characteristics during the spring and summer periods. In this study, particular attention was paid to the role of cloud cover and leads on boundary layer turbulence structure.

PUBLICATIONS:

Wang, S., Q. Wang, R.E. Jordan and P.O. Persson, 2001: Interactions among longwave radiation of clouds, turbulence and snow surface temperature in the Arctic: A model sensitivity study. *Journal of Geophysical Research*, **106**, 15,323-15,333.

Wang, Q. and S. Wang, 2002: Cloud and turbulence in the Arctic Autumnal boundary layers, to be submitted to *Boundary Layer Meteorology*.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Boundary Layer Meteorology, Turbulence Structure, Arctic Research

EVALUATIONS OF SURFACE FLUX AND BOUNDARY PARAMATERIZATIONS IN COAMPS USING AIRCRAFT MEASUREMENTS

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to evaluate the surface flux and boundary layer parameterizations currently used in COAMPS using measurements from Japan/East Sea Experiment (JES).

SUMMARY: It is generally understood that boundary layer parameterization and surface flux parameterization interact nonlinearly in a mesoscale model. The atmospheric forcing to the ocean is thus affected by the boundary layer parameterizations even with perfect formulation of the drag and exchange coefficients. However, such effect has not been quantified. This project intends to evaluate the behavior of the model predicted boundary layer and surface flux in order to improve the model representation of the

lower atmosphere, particularly the surface fluxes. Simulations have been setup using COAMPS for the Japan/East Sea region at NPS for the month of Feb. 2000 during which period observations by the CIRPAS Twin Otter were available. Initial comparison between the observation and the COAMPS model simulation reveals the model tendency in under-predicting wind, temperature, surface stress, and latent heat fluxes in low to moderate wind conditions, while over-predicting most of these quantities in high wind conditions. The subgrid scale turbulent kinetic energy (TKE) is always under-predicted. To understand the model-observation discrepancy, more in-depth analysis of both the model and observed results are underway.

PUBLICATIONS:

Wang, Q., K. Rados, J.A. Kalogiros, H. Zuo, S. Wang, C. Friehe, D. Khelif and H. Jonsson, 2001: Boundary layer turbulence and surface flux parameterizations in a mesoscale model—verification with aircraft measurements. Ninth Conference on Mesoscale Processes, American Meteorology Society., Ft. Lauderdale, FL, 30 July—2 August 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Surface Flux, Boundary Layer Parameterization, COAMPS, Aircraft Measurement

IMPLEMENTING AND TESTING ENTRAINMENT PARAMETERIZATION FOR STRATOCUMULUS-TOPPED BOUNDARY LAYERS IN COAMPS

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to improve the predictions for the stratocumulus-topped boundary layers as well as the cloud-free boundary layers from mesoscale models.

SUMMARY: This 2001 new project intends to first understand the inversion structure at the top of the stratocumulus-topped boundary layer and the fine-scale entrainment process from *in situ* observations. The COAMPS performance against the observed data was systematically evaluated. Within this effort, the feasibility and the successful rate of implementing explicit entrainment parameterization will be assessed and concepts of explicit entrainment parameterization in mesoscale model will be developed and implemented. In 2001, the investigators participated in the field measurement of DYCOMS-II that provides one of the several datasets to be used in the project for COAMPS evaluation. Initial analysis and COAMPS simulation are ongoing.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Stratocumulus-Topped Boundary Layer, Entrainment, Aircraft Measurements

IMPROVING SURFACE FLUX PARAMETERIZATION IN THE NAVY'S COAMPS

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research and Naval Research Laboratory

OBJECTIVE: The objective of this project is to improve surface flux parameterizations, particularly in low-wind conditions.

SUMMARY: The NPS effort on this project focused on understanding the scale-dependence of surface flux and boundary layer parameterizations in high- resolution mesoscale models. Intensive analyses on COAMPS simulations of a post-frontal case observed during JES was performed. In particular, the investigators made spectral analyses to the model resolved field to understand the contribution of 'resolved'

large turbulence eddies to the ensemble turbulent fluxes at very high horizontal grid resolution (1 km and 0.5 km for the inner-most grid, respectively). These results are compared to direct measurements in the model domain. From this initial effort, we found: 1) The perturbations close to the smallest resolvable scale of the model are very sensitive to grid resolution. Compared to observations, these scales are not adequately represented in COAMPS, even though they are explicitly resolved. 2) The model parameterized turbulent fluxes, derived from ensemble turbulence statistics, are not sensitive to the grid resolution even though subgrid fluxes are observed to be strong functions of the cutoff wavelength. 3) There are large discrepancies between the parameterized and the observed SGS turbulence fluxes. All these results point to large uncertainties in the exchange coefficients in the surface flux parameterizations in high-resolution mesoscale models.

In 2001, NRL collaborators have made improvements to the surface flux scheme in COAMPS. The NPS effort also included testing the newly developed surface flux scheme and validating COAMPS simulations using multiple buoy data.

PUBLICATIONS:

Wang, Q. and D.P. Eleuterio, 2001: A comparison of bulk aerodynamic methods for calculating air-sea fluxes. Ninth Conference on Mesoscale Processes, American Meteorology Society, Fort Lauderdale, FL, 30 July–2 August 2001.

Wang, S., J. Doyle and Q. Wang, 2001: Improving surface flux parameterization at low wind speeds in the NAVY's COAMPS. Ninth Conference on Mesoscale Processes, American Meteorology Society, Fort Lauderdale, FL, 30 July–2 August 2001.

Wang, S. and Q. Wang, 2001: Surface flux and stratocumulus clouds in DECS: A mesoscale model study. Fourth Conference on Coastal Atmosphere, FL, 6-9 November 2001.

Whisenhant, M.K., Q. Wang, S. Wang and J. Doyle, 2001: Grid resolution and surface flux and boundary layer parameterizations in high-resolution mesoscale models. Ninth Conference on Mesoscale Processes, American Meteorology Society, Fort Lauderdale, FL, 30 July-2 August, 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Surface Flux Parameterization, Mesoscale Modeling

UNDERSTANDING THE EVOLUTION OF STRATOCUMULUS CLOUDS IN THE COASTAL ZONE

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: The objective of this project is to examine the physical processes affecting the evolution of coastal stratocumulus clouds.

SUMMARY: During the first year of this project (1999), field measurements of the coastal stratocumulus and the associated boundary layer were made off the coast of Monterey using the CIRPAS Twin Otter research aircraft. In 2001, additional efforts were made in calibrating the wind/turbulence measurements by considering the effects of flow distortion. This effort results in new understanding of aircraft measured turbulence in general. A fully calibrated high-rate turbulence data is now available to collaborating research groups.

Efforts were made to study the interaction between the evolution of stratocumulus cloud and the coastal flow field. The effects of the coastal jet on the evolution of stratocumulus clouds were studied through analyses on the case observed on July 6. The variation of the cloud layer along a vertical crosssection due west from Monterey Bay was analyzed. It was found that the strong low-level coastal jet promoted the cloud decoupling from the surface layer and the cloud start thinning quickly. Two

decoupling mechanisms seem to be generated by the jet: i) the negative surface buoyancy flux because the curl of the surface wind stress in the area of the wind jet supports local upwelling which results in a cold pool of sea surface temperature and ii) the enhanced entrainment at cloud top due to wind shear. The decoupling cannot be the result of solar radiation absorption by the cloud alone because it happened in a limited zone only.

Within the same project, we continued the analysis from the previous year on the breakup mechanism of the coastal stratocumulus on the coast using continuous measurements from the Marine Atmospheric Measurement Lab (MAML) at NPS. The time evolution of the boundary layer vertical profiles of wind and temperature before and after the cloud breakup was analyzed. One dimensional simulation using a simple mixed layer cloud model, modified for simulating stratocumulus clouds over the coastal land, was performed to test hypotheses formed based on the observations. The results point to increases in cloud top entrainment and the accompanied warming and drying of the boundary layer air.

PUBLICATIONS:

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DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastal Clouds, Boundary Layer Evolution, Aircraft Turbulence Measurement

COLLABORATIVE RESEARCH PROJECTS IN DIRECT SUPPORT OF FNMOC OPERATIONAL MISSION

Carlyle H. Wash, Professor
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Sponsor: Office of Naval Research

OBJECTIVE: The broad objective of this research is to execute collaborative research projects with the Fleet Numerical Meteorology and Oceanography Center (FNMOC). The collaboration includes NPS Meteorology faculty, NPS students conducting thesis research, and FNMOC personnel. These joint projects address FNMOC operational needs and advance the understanding of marine meteorology.

SUMMARY: Two collaborative thesis projects were supported in FY00 funding. The first project was Improvements to METOC Analysis and Forecast Visualizations by LT Keith Barto. NPS thesis advisor was Professor C. H. Wash and FNMOC collaborator was Mr. Ralph Loveless. In this study, LT Barto incorporated high resolution (1 km) global topography data base into Joint METOC (released as version 3.4) and other FNMOC model and data displays.

The second project is: The Role of Weather in Class A Naval Aviation Mishaps FY 90-98 by LCDR Ruben Cantu NPS; thesis advisors were Professor C. H. Wash and Senior Lecturer Tom Murphree. In this study, 235 Class A Navy and Marine aviation mishaps involving aircrew error between FY90 and 98 were analyzed for role of weather. In addition to determining the overall role of weather, various aspects of the mishaps such as aircraft category, type of mishaps, type of weather and flight phase were investigated.

A third effort is underway. LT Todd Barnhill is working with Professor C. H. Wash and FMNOC advisor Mr. Dave Huff to modernize the FNMOC support and products used in ship routing and ship forecasting. This thesis will be completed in FY2002.

THESIS DIRECTED:

Barto, K., "Improvements to METOC Analysis and Forecast Visualizations," Masters Thesis, Naval Postgraduate School, September 2000.

Cantu, Ruben, "The Role of Weather in Class A Naval Aviation Mishaps FY90-98," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Operational Mission, Marine Meteorology, FNMOC Support

TAMS-RT VERIFICATION AND EVALUATION

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Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The technical objective of this project is to verify and evaluate NPMOC San Diego TAMS-RT and other COAMPS mesoscale forecasts using all available local and mesoscale data.

SUMMARY: This project has established a cassette tape archive of all TAMS-RT San Diego forecasts. In addition one thesis was completed. LCDR Gret Schmeiser, USN, investigated the ability of COAMPS to forecast the major East Coast cyclone of 24-26 January 2000. This storm was of particular interest due to the poor performance of many numerical and human forecasts. LCDR Schmeiser found COAMPS did provide a very accurate storm track and forecast of intensity. However, it failed, as did many other models, in resolving the associated heavy snow and precipitation bands. Some experimental forecasts using the new data assimilation system (NAVDAS) did have positive impacts on the forecasts.

CONFERENCE PAPER:

Wash, C.H. and G. Schmeiser, Verification and Evaluation of NOGAPS and COAMPS Analyses and Forecasts for the 25 January 2000 Cyclone. Preprints, Eighteenth Conference on Weather Analysis and Forecasting, Fort Lauderdale, FL, 30 July–2 August 2001.

THESIS DIRECTED:

Schmeiser, G.J., "Investigation of the 25 January 2000 East Coast Cyclogenesis," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOGY AREAS: Modeling and Simulation

KEYWORDS: Cloud Forecasting, Precipitation Forecasting, COAMPS, Mesoscale Modeling and Forecasting

BOUNDRY LAYER EFFECTS ON MESOSCALE PHENOMENA

R. Terry Williams
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To improve the simulation of boundary layer effects on fronts in coastal regions.

SUMMARY: Maritime frontogenesis was investigated with a two-dimensional model with a K-theory boundary layer parameterization. No moisture was included. It was found that much more intense cold

fronts were predicted over the ocean than over land due to a much smaller z_0 over water. The numerical solutions were similar to intense fronts that have been observed over the ocean.

It was found by numerical integration that boundary layer mixing has a strong effect on cold fronts moving over large-scale topography. In particular the fronts became stronger as they moved up the mountain slope, while the opposite happened when there was no boundary layer.

Unbalanced frontogenesis was examined by considering an initial temperature disturbance with no initial wind. The calculations were carried out with zero potential vorticity that corresponds to zero static stability in the initial state. A frontal discontinuity was obtained when the Rossby number was above a critical value. Otherwise a modified inertial oscillation was obtained.

PUBLICATIONS:

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THESES DIRECTED:

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DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Numerical Models, Topographic Effects, Fronts

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PRESENTATIONS:

Ardhuin, F., W.C. O'Reilly, T.H.C. Herbers, C.V. Tinder and P. Jessen, "Observations and modeling of swell evolution across a wide continental shelf," Proceedings Fourth International Symposium on Ocean Wave Measurement and Analysis, American Society of Civil Engineers, in press.

Ardhuin, F., Herbers, T.H.C., O'Reilly, W.C. and Jessen, P.F., "Validation of a spectral energy balance model for swell on the continental shelf," Eos Transactions AGU, 82(47), Fall Meeting Supplemental, Abstract OS31B-0414, 2001

THESIS DIRECTED:

Ardhuin, F., "Swell Across the Continental Shelf," Ph.D. Dissertation, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality, Battlespace Environments

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Wave Breaking, Bottom Friction, Continental Shelf

COUPLED BIOPHYSICAL MODELING OF THE ARCTIC MARINE RESPONSE TO GLOBAL CHANGE

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Roland W. Garwood, Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To provide a comprehensive understanding of shelf-basin exchange processes, biogeochemical cycles, and their role in the large-scale interannual variability of the Arctic Ocean system and to integrate this knowledge into predictive models of the consequences of global change.

SUMMARY: Some of the most important results from the earlier 18-km and 30-level model include: (i) simulation of the recent (1979-98) large-scale changes in sea ice and the upper ocean circulation in response to atmospheric conditions in qualitative agreement with observations, (ii) finding that the large scale circulation in the Arctic Ocean occurs via narrow (~100km), topographically controlled flows, which require a grid spacing of order 10 km to be adequately represented, (iii) determination of preferred pathways of fresh water transport from the shelves, accumulation in the deep basins and export out of the Arctic Ocean, and their inter-annual to decadal variability.

The ongoing integration of the new 9-km model with 1979-2001 atmospheric forcing will continue during the CY02. Comparisons of the large scale currents and eddy energetics between the two models will be emphasized. In addition to physical improvements of ocean and ice processes, the importance of model resolution in representing details of local dynamics and the main circulation features will be determined.

PUBLICATIONS:

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Preller, R.H., W. Maslowski, D. Stark, P. Posey and T.T.C. Pham, Navy sea ice prediction systems, *The Oceanographic Society*, 2001, in press.

Walczowski, W., W. Maslowski, D.C. Marble and A.J. Semtner, Ocean circulation and shelf-basin exchanges in the Canada Basin from a high resolution model, *AMS Polar Meteorology and Oceanography Conference Extended Abstracts*, 2001.

Walczowski, W., and W. Maslowski, Shelf-basin circulation and exchanges in the Western Arctic high resolution model results, draft manuscript, 2001.

PRESENTATIONS:

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Maslowski, W., W. Walczowski and D.C. Marble, "Environmental conditions in the Western Arctic during 1979-1981 - model results," ARCSS-OAII All Hands Meeting, Salt Lake City, UT, 14-16 November 2001.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Ocean Modeling, Biophysical Environment, Eddies, Shelf-Basin Exchanges

INTERANNUAL VARIABILITY OF BIOPHYSICAL LINKAGES BETWEEN THE BASIN AND SHELF IN THE BERING SEA

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: National Atmospheric and Oceanic Administration

OBJECTIVE: To identify interannual and interdecadal variations in the circulatory and mixing pathways by which nutrients are communicated from the deep ocean to the adjacent shelves in the Bering Sea and western Gulf of Alaska using .an eddy-permitting ice-ocean model of the Pan-Arctic region.

SUMMARY: The coupled ice-ocean model configured at 9-km and 45-level grid was developed and integrated for 50 years. The model domain includes the North Pacific (to ~30oN), the Arctic Ocean, and the North Atlantic (to ~45oN). Model output realistically predicts the net northward transport through Bering Straits and its seasonal and interannual variability. To our knowledge, this is the first model to show such a skill, which is critical for proper modeling of local processes and large-scale circulation in the Bering Sea and the Gulf of Alaska. In the past, global ocean models either did not include the region to the north of Bering Strait or prescribed a fixed northward flow based on observations, due to lack of resolution necessary to properly represent ocean circulation in the region.

Numerical tracers were introduced to allow tracking of Pacific Water pathways and mixing across the Aleutian Archipelago and along the Bering slope, where high nutrient concentrations and increased marine life activities were observed.

The ongoing production integration with 1979-2001 atmospheric forcing will continue during the CY02. Analyses of model results will emphasize physical processes and their role in interannual variability of water mass properties and nutrients in the study region.

PUBLICATIONS:

McClean, J. L., W. Maslowski and M.E. Maltrud, Towards a coupled environmental prediction system, computational science, ICCS 2001, eds: Alexandrov, Dongorra, Juliano, Renner and Tan, *Lecture Notes in Computer Science 2073*, Springer-Verlag, pp. 1098-1107, 2001.

PRESENTATIONS:

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Maslowski, W., Towards eddy-resolving ocean/ice modeling of the pan- Arctic region, An invited seminar at the Artic Region Supercomputing Center Technology Panel, Fairbanks, AK, 12-16 February 2001.

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McClean, J.L, W. Maslowski and M. Maltrud, Towards a coupled environmental prediction system, International Conference on Computational Science, San Francisco, CA, May 2001.

McClean, J.L, W, Maslowski and M. Maltrud, Advanced modeling of the navy operational environments, Part II, DoD HPCMO Users Group Conference, Biloxi, MS, June, 2001.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Ocean Modeling, Biophysical Environment, Eddies, Shelf-Basin Exchanges

MODELING THE LONG-TERM TURBULENT CIRCULATION OF ARCTIC OCEAN AND ITS SEA ICE

Wieslaw Maslowski, Research Associate Professor
Albert J. Semtner, Professor
Yuxia Zhang, Research Assistant Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The main goal of this investigation involved simulation of the long-term circulation of the ice-covered Arctic Ocean driven by realistic atmospheric forcing using advanced parallel computers.

SUMMARY: The most important achievements from the 18-km and 30-level model included: (i) simulation of the recent (1979-98) large-scale changes in sea ice and the ocean circulation in response to atmospheric conditions in qualitative agreement with observations, (ii) finding that the large scale circulation in the Arctic Ocean occurs via narrow (~100km), topographically controlled flows, which require a grid spacing of order 10 km to be adequately represented, (iii) determination of preferred pathways of fresh water transport from the shelves, accumulation in the deep basins and export out of the Arctic Ocean, and their inter-annual to decadal variability, (iv) improved understanding of pathways and distribution of different water masses due to the incorporation of numerical tracers to track them throughout the model simulation.

PUBLICATIONS:

Marble, D.C., W. Maslowski, W. Walczowski, U. Schauer and A.J. Semtner, Simulated annual mass, heat and salt transport through the Barents Sea from an eddy-permitting Pan-Arctic coupled ice-ocean model, *Journal of Geophysical Research*, conditionally accepted, 2001.

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PRESENTATIONS:

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THESIS DIRECTED:

Marble, D.C, "Simulated Annual and Seasonal Arctic Ocean and Sea-ice Variability from a High Resolution Coupled Ice-ocean Model," Ph.D. Dissertation, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Ocean Modeling, Climate Change, Ice-Ocean Interactions, Decadal Variability

COMPARISONS OF THE LANL POP MODEL AND WOCE OBSERVATIONS

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Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To evaluate the global 0.28°, 20-level Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) model with observational data collected during the World Ocean Circulation Experiment (WOCE).

SUMMARY: Two new POP simulations were run and analyzed to correct deficiencies identified by earlier comparisons of the 0.28°, 20-level POP model with the WOCE data. Eulerian and Lagrangian velocity statistics were calculated from North Atlantic surface drifting buoys and a new 0.1°, 40-level North Atlantic configuration of POP. The high-resolution model produced a very realistic ocean state for 1993-1997 in terms of mean flows, energy levels, and intrinsic scales. A two-decade repeat-XBT line collected between Java and Australia was compared with co-located output from a 1/3°, 32-level global POP simulation. The seasonal to interannual variability found in the data was well reproduced by the model. The larger space-time context of the model was then used to understand the causes of this variability.

PUBLICATIONS:

McClean, J.L., W. Maslowski and M.E. Maltrud, Towards a coupled environmental prediction system, *Computational Science - ICCS 2001*, eds: Alexandrov, Dongorra, Juliano, Renner, and Tan, Lecture Notes in Computer Science 2073, Springer-Verlag, pp 1098-1107, 2001.

McClean, J.L., P.-M. Poulain, J.W. Pelton and M. Maltrud, Eulerian and Lagrangian statistics from surface drifters and two POP models in the North Atlantic. *Journal of Physical Oceanography*, 2001, accepted.

PRESENTATIONS:

McClean, J.L. and M. Maltrud, Mass and heat transports in the global 0.28-degree POP model. South Atlantic Model-Data Meeting, Los Alamos National Laboratory, Los Alamos, NM, March 2001.

McClean, J.L., High resolution ocean modeling for synoptic forecasting and short-term climate studies, Invited Seminar, Romberg-Tiburon Center, San Francisco State University, CA, April 2001.

McClean, J.L., P.-M. Poulain, J.W. Pelton, M. Maltrud and D. Ivanova, Eulerian and Lagrangian statistics from surface drifters and two POP models in the North Atlantic, Western Boundary Current Virtual Poster Session, http://www.gso.uri.edu/wbc/Mcclean, May 2001.

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

KEYWORDS: Ocean Circulation, Model Validation, Model/Data Synthesis

EVALUATIONS OF THE POP MODEL FOR NAVY FORECASTING USE

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Robin T. Tokmakian, Research Assistant Professor
Albert J. Semtner, Professor
Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To continue high-resolution simulations and analyses of the Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) model for global Navy forecasting needs. This project is ongoing.

SUMMARY: The spin-up phase of a 0.1°, 40-level global configuration of the POP model continued along with assessments of its realism. These assessments were made by comparing appropriate data sets with the model solution. Sensitivity studies were conducted in basins where the model solution was found to be unrealistic to identify the causes of these behaviors and correct them. In particular, mixed layer dynamics, key basin overflows, and western boundary current separations and flows were examined.

PUBLICATIONS:

McClean, J.L., W. Maslowski and M.E. Maltrud, Towards a coupled environmental prediction system, *Computational Science - ICCS 2001*, eds: Alexandrov, Dongorra, Juliano, Renner, and Tan, Lecture Notes in Computer Science 2073, Springer-Verlag, pp. 1098-1107, 2001.

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PRESENTATIONS:

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

KEYWORDS: Ocean Circulation, Model Validation, Model/Data Synthesis

AN INNOVATIVE COASTAL-OCEAN OBSERVING NETWORK

Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to show that real-time data from HF radars and acoustic tomography can improve the performance of coastal circulation and biological productivity models.

SUMMARY: A concept demonstration is underway by a consortium of government, academic, and industrial partners to show how a diverse suite of modern, innovative ocean instrumentation can be successfully integrated into a functional, real-time ocean observation network. The plan calls for both creative application of well established observational techniques and the development of new instrumentation and algorithms, which will be utilized in the network for the very first time. Moored, single-point time series observations, remotely-sensed data, ocean acoustic tomography, and two-dimensional vector fields obtained from HF radars are being integrated into a cohesive picture of the coastal environment via a nested, high resolution numerical model. The sensor data and model output are being made available via Internet web pages for immediate application by coastal managers, defense analysts, emergency response teams, and commercial and recreational use.

PUBLICATIONS:

Shulman, I., C.-R. Wu, J.K. Lewis, J.D. Paduan, L.K. Rosenfeld, J.D. Kindle, S.R. Ramp and C.A. Collins, High resolution modeling and data assimilation in the Monterey Bay area. *Continental Shelf Research*, in press, 2001.

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PRESENTATIONS:

Cook, M.S., J.D. Paduan, I. Shulman, D.M. Fernandez and C. Whelan, Statistics and data assimilation results from long-term HF radar-derived surface currents around Monterey Bay. Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf Lake, CA, 23-26 September 2001.

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Paduan, J.D., Cook, M.S., I. Shulman, D.M. Fernandez and C. Whelan, Statistics and data assimilation results from long-term HF radar-derived surface currents around Monterey Bay. First Radiowave Oceanography Workshop, Timberline Lodge, Mt. Hood, OR, 9-12 April 2001.

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THESIS DIRECTED:

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OTHER:

Rosenfeld, L.K. and J.D. Paduan, "An Innovative Coastal-Ocean Observing Network (ICON)." Invited presentation, FNMOC Open House, Monterey, CA, 21 April 2001.

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

KEYWORDS: HF Radar, Ocean Currents, Air-Sea Interaction

DIURNAL TO SEASONAL VARIABILITY OF SURFACE OCEAN CURRENTS FROM HIGH FREQUENCY RADAR

Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsors: National Science Foundation and Naval Postgraduate School

OBJECTIVE: The goals of this project are to describe the wind and tide forcing of the upper ocean currents around Monterey Bay and to develop optimized HF radar current algorithms.

SUMMARY: This research is drawing on data from a unique array of five HF radar systems around Monterey Bay: three CODAR-SeaSonde direction-finding systems and two multi-frequency phased array systems. Focus is on the 2-D surface currents and how they vary, both seasonally and daily, compared with measured winds and satellite AVHRR images. Data from the multi-frequency radar sites is being used to measure near-surface shear, which is difficult to do with in situ instrumentation. In addition, data from these systems, as well as simulations, is being used to examine the sensitivity of radar algorithms to varying current and wave conditions.

PUBLICATIONS:

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Laws, K., D.M. Fernandez and J.D. Paduan, Simulation-based evaluations of HF radar ocean current algorithms. *Journal of Oceanic Engineering*, 25, 481-491, 2001.

Paduan, J.D., D. Barrick, D. Fernandez, Z. Hallock and C. Teague, Improving the accuracy of coastal HF radar current mapping. *Hydro International*, 5, 26-29, 2001.

PRESENTATIONS:

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Paduan, J.D., K. Laws and D.M. Fernandez, Effect of Stokes Drift on HF radar measurements. First Radiowave Oceanography Workshop, Timberline Lodge, Mt. Hood, OR, 9-12 April 2001.

THESIS DIRECTED:

Laws, K., "Measurements of Near Surface Ocean Currents Using HF Radar," Ph.D. Dissertation, University of California Santa Cruz, June 2001.

OTHER:

Paduan, J.D., "HF radar measurements of ocean currents," Invited seminar, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy, 12 October 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: HF Radar, Ocean Currents, Air-Sea Interaction

GLOBEC MAPPING THE EVOLUTION OF MESOSCALE JETS AND EDDIES IN THE UPWELLING ECOSYSTEM OFF CAPE BLANCO, OREGON USING LONG RANGE HIGH FREQUENCY RADAR

Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The goal of this project is to demonstrate the viability of long range high frequency radar for mapping ocean currents out to 200 km from shore.

SUMMARY: This research is deploying a new application of High Frequency (HF) radar instruments for extended range coverage of filaments and eddies in the California Current System with specific application to the mesoscale jets and eddies in the upwelling system of Cape Blanco, OR in support of GLOBEC processes studies sited in that area.

PRESENTATIONS:

Cook, M.S. and J.D. Paduan, Processing HF radar data using the HFRadarmap software system. First Radiowave Oceanography Workshop, Timberline Lodge, Mt. Hood, OR, 9-12 April 2001.

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

KEYWORDS: HF Radar, Ocean Currents, Air-Sea Interaction

MODELING THE CENTRAL CALIFORNIA COASTAL UPWELLING SYSTEM: PHYSICS, ECOSYSTEMS AND RESOURCE MANAGEMENT

Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: The goal of this project is to incorporate a multi-component ecosystem model within a circulation model of the central California coastal region.

SUMMARY: This project is modeling the oceanographic processes within the Monterey Bay National Marine Sanctuary (MBNMS) at high resolution (kms). A large body of observations is available from the region for model validation. The high-resolution coastal model will be nested within basin-scale and regional models. The model will include physical, chemical and biological properties and be capable of assimilating data from satellites and in situ sensors. The model will focus on simulating the observed strong seasonal and interannual variations in oceanographic processes. NPS scientists will participate through quality control and interpretation of physical oceanographic data sets from the Monterey Bay region.

OTHER:

Paduan, J.D., "Results from modeling and HF radar studies in Monterey Bay," SCOPE workshop, University of California Los Angeles, CA, 23-25 April 2001.

Paduan, J.D., "More Results from modeling and HF radar studies in Monterey Bay," SCOPE workshop, MBARI, Moss Landing, CA, 11-12 December 2001.

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

KEYWORDS: HF Radar, Ocean Currents, Air-Sea Interaction

REAL-TIME OBSERVATIONS OF A COASTAL UPWELLING EVENT USING INNOVATIVE TECHNOLOGIES

Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The goal of this project is to apply a unique suite of coastal ocean observations and models to the description and prediction of complex frontal processes.

SUMMARY: A field program was conducted in August 2000 to study the spatial and temporal evolution of a coastal upwelling front near Pt. Año Nuevo, California (20 km north of Monterey Bay). The field effort represented enhancements to the ONR Autonomous Ocean Sensing Network (AOSN) and Innovative Coastal-ocean Observing Network (ICON) programs. New observational and modeling tools and real-time data delivery were used to study the front at smaller space and time scales than has previously been possible with the scientific objective to understand how strong vertical motions impact the secondary circulations around the front. Daily aircraft overflights were used to: 1) Precisely locate the front by observing the sea surface temperature, color, and roughness; and 2) to collect a full suite of atmospheric data. Point measurements were made using a bottom-mounted ADCP from the NPS Rapid Environmental Assessment Laboratory (REAL) transmitting in real-time via acoustic modem. Remotely operated vehicles from the AOSN program mapped properties, including bioluminescence potential. A special enhanced-resolution run of the ICON nested, data assimilating circulation model was conducted to interpret and extend the measurements.

PRESENTATIONS:

Ramp, S.R., J.D. Paduan, F.L. Bahr, R. Bluth, D. Frye, P. Koski, F. Chavez and J. Reid, Atmospheric forcing and oceanic response during late summer upwelling and relaxation events in Monterey Bay. Oceanography Society Annual Meeting, Miami, FL, 3-5 April 2001.

Ramp, S.R., J.D. Paduan, F.L. Bahr, R. Bluth, D. Frye, P. Koski, F. Chavez and J. Reid, Atmospheric forcing and oceanic response during late summer upwelling and relaxation events in Monterey Bay. Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf Lake, CA, 23-26 September 2001.

OTHER:

Paduan, J.D., S.R. Ramp and I. Shulman, "Real-time observations and retrospective model results during MUSE." ONR Bioluminescence workshop, MBARI, Moss Landing, CA, 6-7 September 2001.

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

KEYWORDS: HF Radar, Ocean Currents, Air-Sea Interaction, Bioluminescence

MEDITERRANEAN DRIFTER ANALYSIS

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Sponsor: Office of Naval Research

OBJECTIVE: It is proposed to assess the water-following capabilities of commonly-used surface drifters by performing sea tests in which prototype drifters equipped with acoustic velocimeters and GPS receivers will be deployed in various wind/wave conditions.

SUMMARY: More than 500 surface drifters have been used between 1986 and 1999 to measure the sea surface circulation and temperature in the Mediterranean Sea. The velocity statistics estimated from this dataset are affected by instrumental and sampling error. The most important instrumental error is due to the action of wind/waves on the drifters, causing it to "slip" with respect to the water. Sampling errors on velocity statistics, such as the "array" bias, an important error when the lagarian data are non distributed uniformly in space, will be estimated using statistical models for the prediction of drifter trajectories. Optimized drifter deployment strategies will also be sought.

DoD KEY TECHNOLOGY AREAS: Environmental Quality, Battlespace Environments

KEYWORDS: Circulation, Lagrangian Drifers, Remote Sensing, Mediterranean Sea

MEDITERRANEAN SURFACE CIRCULATION STUDIES

Pierre-Marie Poulain, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The spatial structure and the temporal variability of the surface circulation of the Mediterranean Sea will be studied using a comprehensive drifter data set and ancillary satellite observation.

SUMMARY: First, seasonal maps of the Mediterranean surface mean currents and eddy variability will be compiled. Lagrangian statistics (Eddy Difusivity, time and space scales) will also be estimated. Second, horizontal fluxes of momentum and heat near the surface of the Adriatic and Ionian Seas will be estimated from the drifter and satellite data. They will be related to the surface atmospheric fluxes as provided by wind products and observations. Third, the drifter data will be combined with passive remote sensing data (sea surface temperature and ocean color) to study the mesoscale circulation in selected regional areas, such

as the Adriatic Sea and the Straits of Sicily region. Finally, studies will be conducted to compare modeled and observed near-surface drifter trajectories in the Adriatic with the goal of improving future drifter deployment strategies and of assessing model capabilities.

DoD KEY TECHNOLOFY AREAS: Environmental Quality, Battlespace Environements

KEYWORDS: Circulation, Lagrangian Drifters, Remote Sensing, Mediterranean Sea

GLOBEC: MOORED CURRENT OBSERVATIONS ALONG THE EUREKA LTOP TRANSECT

Steven R. Ramp, Research Professor
Department of Oceanography
Sponsor: National Oceanic Atmospheric Agency

OBJECTIVE: The over-arching goal of the Global Ocean Ecosystems Dynamics (GLOBEC) Northeast Pacific Program (NEP) is to understand the effects of climate variability and climate change on the distribution, abundance and production of marine animals in the eastern North Pacific Ocean. The objective of the five-year Long-Term Observation Program (LTOP) moorings is to monitor the temporal and spatial variability of the currents and bottom temperature over the continental shelf off Oregon, from tidal to interannual scales, and relate this physical variability to long-term changes in the ecosystem.

SUMMARY: Oceanographic moorings to measure temperature, salinity, and velocity at the 73 m isobath 6.5 nm off the mouth of the Rouge River near Gold Beach, OR have now been maintained by NPS since May 2000. Following the loss of one instrument during the first deployment, some design changes to the hardware were made and there has been a 100% recovery rate ever since. The moorings are still in the ocean and will be recovered and redeployed again during April and October 2002. The data are being analyzed in conjunction with other moorings off Coos Bay and Newport, OR, maintained by other GLOBEC investigators. Early results indicate significant differences in the environment north (Coos Bay) and south (Rogue River) of Cape Blanco, OR, where the coastal jet separates from the coast. The physical changes apparently propagate through the ecosystem as larger numbers salmon, birds, and marine mammals were also observed south of Cape Blanco than north. Occasional onshore advection events of Columbia River Plume water have also been noted. The Principal Investigators are working with the GLOBEC biologists to understand these results. The first journal publications from the GLOBEC NEP program are targeted for the coming fiscal year.

PUBLICATIONS:

Batchelder, H., T. Strub, W. Peterson, J.A. Barth, P.M. Kosro, R. Brodeur, C. Tynan, L. Botsford, T. Powell, F. Schwing, D. Ainley, M. Ohman, T. Mackas, B. Hickey, S.R. Ramp and R. Letelier, The GLOBEC Northeast Pacific program: California current system. *Oceanography Magazine*, 2001, submitted.

PRESENTATIONS:

Ramp, S.R., P.M. Kosro, A. Huyer and T. Strub, The GLOBEC Rogue River time series. Second GLOBEC NEP Investigators Workshop, Seattle, WA, November 2000.

OTHER:

Two oceanographic research cruises per year on the R/V WECOMA off the Oregon coast.

DoD KEY TECHNOLOFY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Coastal Oceanography, Upwelling Fronts, Ecosystem Dynamics, GLOBEC

THE INNOVATIVE COASTAL-OCEAN OBSERVING NETWORK (ICON)

Steven R. Ramp, Research Professor
Jeffrey D. Paduan, Associate Professor
Curtis A. Collins, Professor
Leslie K. Rosenfeld, Associate Research Professor
Department of Oceanography
Sponsor: National Ocean Partnership Program

OBJECTIVE: The ICON objective is to develop and integrate real-time observing systems into a nested, data-assimilating model of the Monterey Bay. The system will serve as a model for future coastal ocean monitoring and prediction networks and can be transported and applied to other geographic regions of high tactical interest. The project has many partners at other institutions.

SUMAMRY: A concept demonstration is underway by a consortium of government, academic, and industrial partners to show how a diverse suite of modern, innovative ocean instrumentation can be successfully integrated into a functional, real-time ocean observation network. The plan calls for both creative application of well established observational techniques and the development of new instrumentation and algorithms, which will be utilized in the network for the very first time. Moored, single-point time series observations, remotely-sensed data, ocean acoustic tomography, and two-dimensional vector fields obtained from HF radars are being integrated into a cohesive picture of the coastal environment via a nested, high resolution numerical model. The sensor data and model output are being made available via Internet web pages for immediate application by coastal managers, defense analysts, emergency response teams, and commercial and recreational use.

PUBLICATIONS:

Shulman, I., C.-R. Wu, J.K. Lewis, J.D. Paduan, L.K. Rosenfeld, J.D. Kindle, S.R. Ramp and C.A. Collins, High resolution modeling and data assimilation in the Monterey Bay area. *Continental Shelf Research*, 2001, in press.

Ramp, S.R., D.E. Barrick, L.A. Pederson, J.C. Lee, J.D. Paduan and I. Shulman, Recent advances in coastal HF radars with potential application to the Asian marginal seas. *Proceedings, Eleventh PAMS/JECSS Workshop*, Cheju, Korea, 11-13 April 2001.

Shulman, I., J.D. Paduan, C.-R. Wu, J.K. Lewis, L.K. Rosenfeld and S.R. Ramp, High frequency radar data assimilation in the Monterey Bay. *Proceedings Seventh International Estuarine and Coastal Modeling Conference*, St. Petersburg, FL, November 2001.

PRESENTATIONS:

Rosenfeld, L.K., R. Durazo, I. Shulman, J.D. Paduan, D. Blencoe, S. Ramp and C. Collins, Comparison between modeled and measured velocity and temperature fields from an Innovative Coastal-Ocean Observing Network (ICON). Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf Lake, CA, 23-26 September 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Coastal Oceanography, Upwelling Fronts, Monitoring and Prediction, Real-time Data

PROCESSES IN MARGINAL SEAS AND ASIAEX PROJECT MANAGEMENT

Steven R. Ramp, Research Professor
Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective of these two closely-related projects is to plan and execute a multi-national oceanographic field program in the East and South China Seas to investigate how the complex littoral environment (i.e., its water column, boundary, sediment and sub-bottom structure and inhomogenities) affects the ray paths, mode structure, propagation loss, and temporal and spatial (both vertical and horizontal) coherence for low-to-intermediate frequency (50-4000 Hz) acoustic transmissions in shallow water. The work is part of a continuing project.

SUMMARY: Several years of advance planning and hard work came to fruition this year with the successful execution of the ASIAEX main field program during April-June 2001. The South China Sea (SCS) portion took place during April - May 2001 on the Chinese continental shelf and slope between Dongsha Island and Taiwan. The East China Sea (ECS) portion took place during May and June in the region bounded by 28-30°N and 126(30' to 128°E. Professors Ramp and Chiu were principal investigators in the SCS program, which was executed during eight cruises from three Taiwanese research vessels. Eight oceanographic moorings, eight acoustic source/receiver moorings, and numerous smaller, experimental moorings were deployed and recovered. The area was also surveyed using the SeaSoar towed undulating vehicle and a chirp sonar sub-bottom profiling system. This is the largest simultaneous, high-resolution physical oceanography and acoustic propagation data set ever collected. The data will take several years to analyze and understand. This process has just begun as of this writing.

Profs. Ramp and Chiu also serve as the International Scientific Coordinator and Assistant Coordinator respectively for both the SCS and ECS ASIAEX programs. They convened a planning workshop in Monterey, CA during December 2000, traveled to Beijing, PRC for another planning workshop in spring 2001, and convened the first post-experiment workshop in Maui, Hawaii during 29 October-2 November 2001, to begin the data exchange and analysis process.

PUBLICATIONS:

Ramp, S.R., F.L. Bahr, C.J. Ashjian and L.D. Talley, The upper-ocean circulation in the Ulleung Basin during June-July 1999. *Deep-Sea Research*, II, 2001, submitted.

Ramp, S. R., *The Asian Seas International Acoustics Experiment (ASIAEX),* Naval Postgraduate School Technical Report, NPS-OC-01-001, 31 pp. 21-23 June 2000.

Ramp, S.R., C.S. Chiu, J.F. Lynch and P.H. Dahl, "ASIAEX Program A Huge Success!" *Naval Postgraduate School Research Newsletter*, 11, No. 3, 24-26 and 51-54, 2001.

Chiu, C.S., S.R. Ramp and J.F. Lynch, The ASIAEX 2000 preliminary experiment in the East China Sea (ECS). *Proceedings Fifth International Conference in Theoretical and Computational Acoustics*, Beijing, PRC, 2001.

PRESENTATIONS:

Ramp, S.R., Results from the Asian Seas International Acoustics Experiment (ASIAEX) environmental moorings in the South China Sea, ASIAEX Workshop, Maui, HI, October 2001.

Ramp, S.R., Physical oceanography of the South and East China Seas, COMSUBPAC/NPS Workshop, Monterey, CA, February 2001.

THESIS DIRECTED:

Rocha, J.D., "SeaWiFS Analysis of the Japan and East China Sea Air/Sea Environment," Masters Thesis, Naval Postgraduate School, December 2001.

OTHER:

In the process of transitioning new operational knowledge of the Asian marginal seas to COMPACSUBFLT in Pearl Harbor, Honolulu, HI.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Marginal Seas, Mesoscale Dynamics, Environmental Acoustics, ASIAEX

REAL-TIME OBSERVATIONS OF A COASTAL UPWELLING EVENT USING INNOVATIVE TECHNOLOGIES

Steven R. Ramp, Research Professor
Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The goal of this project is to apply a unique suite of coastal ocean observations and models to the description and prediction of complex frontal processes.

SUMMARY: A field program was conducted in August 2000 to study the spatial and temporal evolution of a coastal upwelling front near Pt. Año Nuevo, California (20 km north of Monterey Bay). The field effort represented enhancements to the ONR Autonomous Ocean Sensing Network (AOSN) and Innovative Coastal-ocean Observing Network (ICON) programs. New observational and modeling tools and real-time data delivery were used to study the front at smaller space and time scales than has previously been possible with the scientific objective to understand how strong vertical motions impact the secondary circulations around the front. Daily aircraft overflights were used to: 1) Precisely locate the front by observing the sea surface temperature, color, and roughness; and 2) to collect a full suite of atmospheric data. Point measurements were made using a bottom-mounted ADCP from the NPS Rapid Environmental Assessment Laboratory (REAL) transmitting in real-time via acoustic modem. Remotely operated vehicles from the AOSN program mapped properties, including bioluminescence potential. A special enhanced-resolution run of the ICON nested, data assimilating circulation model was conducted to interpret and extend the measurements.

PRESENTATIONS:

Ramp, S.R., J.D. Paduan, F.L. Bahr, R. Bluth, D. Frye, P. Koski, F. Chavez and J. Reid, Atmospheric forcing and oceanic response during late summer upwelling and relaxation events in Monterey Bay. Oceanography Society Annual Meeting, Miami, FL, 3-5 April 2001.

Ramp, S.R., J.D. Paduan, F.L. Bahr, R. Bluth, D. Frye, P. Koski, F. Chavez and J. Reid, Atmospheric forcing and oceanic response during late summer upwelling and relaxation events in Monterey Bay. Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf Lake, CA, 23-26 September 2001.

OTHER:

Ramp, S.R., J.D. Paduan and L.K. Rosenfeld, "Physical oceanography considerations for a bioluminescence experiment." ONR Bioluminescence Workshop, MBARI, Moss Landing, CA 6-7 September 2001.

Paduan, J.D., S.R. Ramp and I. Shulman, "Real-time observations and retrospective model results during MUSE." ONR Bioluminescence Workshop, MBARI, Moss Landing, CA, 6-7 September 2001.

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

KEYWORDS: Real-time Observations, Ocean Currents, Air-Sea Interaction, Bioluminescence

IN-SITU EVALUATION OF OCEANOGRAPHIC PRODUCTS FOR THE METOC COMMUNITY

Leslie Rosenfeld, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: i) Evaluate the Navy Meteorology and Oceanography (METOC) community's use of oceanographic products in the regional METOC centers and facilities. ii) Suggest ways in which the METOC community could improve their oceanographic support, through changes that could be made to improve the utility of their ocean products, introduction of new products, and changes in training to allow METOC personnel to take better advantage of the ocean products available to them. iii) Identify data and technology available through the academic and government research community that could be of use to the operational community. iv) Facilitate cooperation and collaboration between regional METOC centers and facilities and nearby civilian, or non-Navy government, oceanographic centers. v) Provide feedback to the Naval Postgraduate School Oceanography Department on how their graduates are faring, and what changes could be made to the curricula to help future graduates in their careers. vi) Provide on-site assistance and training in the use of oceanographic data and models.

SUMMARY: All of the Navy METOC centers and facilities were visited for periods of time ranging from two to six weeks each. Time was also spent with METOC officers and divisions on ships and staffs, and at a few detachments and components. Stops were also made at METOC production and training centers. Routine operations, fleet exercises, and actual missions were observed. Each command's classified and unclassified web sites were examined. There was extensive interaction with ocean services and fleet liaison personnel at each of the centers, as well as with the science and technology officers and Naval Oceanographic Office (NAVO) fleet representatives. Working papers were prepared on several topics of concern, including: surface wave models, the Modular Ocean Data Assimilation System, Navy operational ocean circulation and tide models, and training. Feedback was provided to NAVO and the Fleet Numerical Meteorological and Oceanographic Center on their ocean products. Connections were facilitated between the regional centers and nearby universities with physical oceanography departments, including: University of Tokyo, Old Dominion University, University of Cadiz, University of Washington, and University of Hawaii. Verbal outbriefs and written reports were delivered to each METOC center and facility Commanding Officer.

PUBLICATIONS:

Wash, C.H. and L.K. Rosenfeld, *The Role of Navy METOC Regional Centers and Facilities in the New Millennium: Thoughts from a Sabbatical Tour*, Naval Postgraduate School, Technical Report, NPS-MR-01-002, Monterey, CA, pp.14, 2001.

OTHER:

The results of this work were presented as verbal briefs to the Commander, Naval Meteorology and Oceanography Command in Bay St. Louis, MS in November 2000, and to the Oceanographer of the Navy in Washington, D.C. in December 2000.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Operational Oceanography

INVESTIGATION OF SOURCE OF HUNTINGTON BEACH SEWAGE CONTAMINATION

Leslie Rosenfeld, Research Associate Professor
Department of Oceanography
Sponsor: Orange County Sanitation District

OBJECTIVE: The goal of this project is to determine whether Orange County Sanitation District's (OCSD) ocean outfall could be the source of sewage contamination to the surf zone off Huntington Beach, California.

SUMMARY: During 2001, a field project was undertaken to determine whether OCSD's ocean outfall could be the source of bacterial contamination to the Huntington Beach surf zone. Planning activities were carried out in the early part of the year and then measurements of the nearshore circulation and water properties in the region were made during the summer. A number of institutions, agencies, and companies were involved. NPS's part involved deploying current, temperature, salinity, wind and wave measuring instruments in June and recovering them in October. All NPS instruments returned good data and initial data processing was completed in the fall. The data were submitted to SAIC which brought data from all the participants together in a common format. The complete data set was distributed to all participants in early 2002 for further analysis.

PRESENTATIONS:

Rosenfeld, L.K. et al., Field study of possible cross-shelf transport mechanisms for a treated wastewater plume discharged on the continental shelf off Huntington Beach, CA. Ocean Sciences, Honolulu, HI, 11-15 February 2002.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastal Circulation, Sewage Outfalls, Huntington Beach

APPLICATION OF PARALLEL OCEAN AND CLIMATE MODELS TO DECADE/CENTURY PREDICTION

Albert J. Semtner, Professor
R. Tokmakian, Research Assistant Professor
W. Maslowski, Research Assistant Professor
J. McClean, Research Assistant Professor
Y. Zhang, Research Assistant Professor
Department of Oceanography
Sponsors: U.S. Department of Energy and Naval Postgraduate School

OBJECTIVE: To use ocean, atmosphere, and ice models developed during earlier research under the DOE CHAMMP Program in order to simulate realistic climate states using advanced parallel computers. To understand physical processes that affect oceanic predictability and climatic fluctuations or change.

SUMMARY: This five-year project is in its fourth of five years. It uses various advanced models to understand the variability of ocean and ocean-ice circulation at relatively high resolution. The NPS group collaborates with large climate modeling efforts at Los Alamos and at the National Center for Atmospheric Research. Extensive simulations were carried out last year, and analysis is underway.

PUBLICATIONS:

Maslowski, W., D.C. Marble, W. Walczowski and A.J. Semtner, On large-scale shifts in the Arctic Ocean and sea ice conditions during 1979-98, *Annals of Glaciology*, 2001, in press.

McClean, J.L., P.-M. Poulain, J.W. Pelton and M. Maltrud, Eulerian and Lagrangian statistics from surface drifters and a high resolution POP simulation in the North Atlantic. *Journal of Physical Oceanography*, 2001, accepted.

Tokmakian, R., The relationships between the low frequency signals in an ocean model and altimetry data, *Journal of Geophysical Research*, 2001, submitted.

Zhang, Y. and A.J. Semtner, The Antarctic circumpolar wave in a high-resolution ice-ocean simulation, *Annals of Glaciology*, 2001, in press.

PRESENTATIONS:

Maslowski, W., 1/12-degree pan-Arctic coupled ice-ocean model - spinup results, Climate Change Prediction Program Meeting, San Diego, CA, 1-3 October 2001.

Pierce, D.W., T.P. Barnett, W.M. Washington, A. Semtner, T. Bettge, R. Tokmakian, G. Chukkapalli, ACPI Elements 1 and 2: Initializing the coupled model from observed ocean conditions and the ensemble runs, San Francisco AGU Meeting, San Francisco, CA, December 2001.

McClean, J.L and M. Maltrud, High resolution POP, CCPP Meeting, San Diego, CA, October 2001.

Semtner, A.J. and Y. Zhang, Polar ocean circulation, variability, and anthropogenic change, as depicted in high-resolution coupled models, Gordon Conference on Polar Marine Science, Ventura, CA, 12-16 March 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical Modeling, Ocean Prediction, Parallel Computing

SIMULATIONS AND RECONSTRUCTIONS OF GLOBAL OCEAN CIRCULATION WITH WELL-RESOLVED EDDIES FOR THE WOCE OBSERVATIONAL PERIOD

Albert J. Semtner, Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The goal was to further improve on the realism of numerical models of global three-dimensional ocean circulation, with important currents well depicted and to conduct simulations using the best available atmospheric forcing. The 7-year project finished in 2001.

SUMMARY: Last year, a model was developed with 2/3-degree global grid and 40 vertical levels, with improved physics, and with proper representation of coastlines and depths. The 40-year reanalysis fields of the National Centers for Environmental Prediction were prepared as forcing. Robin Tokmakian simulated conditions of 1959-98, starting from the best available climatology. A massive amount of model output was analyzed and compared with in-situ and satellite observations. Model output was provided to many requesting groups.

PUBLICATIONS:

Boening, C. and A.J. Semtner, High-resolution modelling of the thermohaline and wind-driven circulation, Chapter 2.2 of *The World Ocean Circulation Experiment*, J. Gould and J. Church, eds., Cambridge University Press, Cambridge, UK, pp. 59-77, 2001.

Tokmakian, R., The relationships between the low frequency signals in an ocean model and altimetry data, *Journal of Geophysical Research*, 2001, submitted.

Montano, R.P., E.J., Beier, P.T. Strub and R. Tokmakian, Large-scale forcing of the Agulhas variability: the seasonal cycle, *Journal of Geophysical Research*, 2001, in press.

PRESENTATIONS:

Semtner, A.J., High-resolution Global Ocean and Arctic Ocean-ice forecast systems being developed at the Naval Postgraduate School, Computing in the Atmospheric Sciences, Annecy, France, 29 October- 1 November 2001.

Tokmakian, R., Forty-plus year hindcast ocean simulation, CCPP presentation, San Diego, CA, 1 October 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical Modeling, Ocean Prediction

OBSERVATION OF VELOCITY FIELDS UNDER WIND-FORCED WAVES

Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: The objectives of this research are to measure and model the transfer of wind-stress through surface turbulence and waves at the air-sea interface. This momentum transfer via surface gravity waves remains poorly understood due primarily to the difficulties of measuring turbulence immediately below the wave surface.

SUMMARY: During the first year of funding on this program, prototype measurements of velocity fields below surface gravity waves were made in shallow water offshore from the NPS Marine Operations facility in Monterey Bay. A unique small scale coherent Doppler velocity profiler, the BCDVSP, was directed up under waves from a stable platform in 3.5m depth. Three component velocity profiles were measured every 1.5cm over a 1.5m range spanning the wave crest/trough region. These data sets have allowed a surface-following analysis technique to be developed to measure timeseries of vertical Reynolds stresses along with near-surface shear profiles, allowing shear production rates to be estimated. These results were presented at the fall SA and AGU meetings. Instrument developed continued for the main deployment in the summer of 2002 at the WHOI Marthas Vineyard tower.

PRESENTATIONS:

Stanton, T.P., Field observations of velocity structure directly below wind-forced waves. Waves 2001, San Francisco, CA, September 2001.

Stanton, T.P., Observations of turbulence in ocean wave boundary layers, Fall ASA Meeting, Fort Lauderdale, FL, December 2001.

PATENT:

Stanton, T.P., 2001. A Turbulence-Resolving Coherent Acoustic Sediment Flux Probe Device and Method For Using. U.S. Patent 6,262,942, issued 17 July 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Wave Dissipation, Shoaling Waves, Bottom Boundary Layers

SPECTRAL WAVE DECAY DUE TO BOTTOM FRICTION ON THE INNER SHELF

Timothy P. Stanton, Research Associate Professor
E. B. Thornton, Distinguished Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: The objectives of this research are to directly measure wave dissipation as surface gravity waves propagate across continental shelves. Observations of dissipation in the thin oscillatory bottom boundary layer, bottom morphology and low frequency currents are being used to develop a spectral wave model of dissipation for use in shelf wave models.

SUMMARY: Analysis continued of wave forced bottom boundary layer observations made at Duck during the SHOWEX program. The Bistatic Coherent Doppler Velocity and Sediment Profiler and a scanned X/Y altimeter, both developed at NPS, were deployed at Duck, NC on an instrument frame in 12m depth allowing the response of the bottom boundary layer to a wide range of wave and currents to observed. Estimates of RMS shear and Reynolds stresses across the thin oscillatory boundary layer are being used to estimate the wave-work rate as the local bedforms evolve in response to the wave forcing. These measurements have been replicated in a coarser sediment bed, narrow-banded wave environment as a component of the long term Monterey Inner Shelf Observatory, MISO (http://www.oc.nps.navy.mil/~stanton/miso).

Two analysis techniques have been developed to estimate profiles of Reynolds stresses, shear and hence shear production of TKE. A paper describing the BCDVSP measurements of stresses in the wave and mean current boundary layers has been prepared for a SHOWEX special issue in JOAT. A paper describing the morphology measurement methods is also being submitted. A thesis project comparing bedform evolution with the DUNE2D model was completed, with preliminary results presented at the Fall AGU.

PRESENTATIONS:

Martin, S.D., E.B. Thornton and T.P. Stanton, DUNE2D modeling of vortex ripple migration, American Geophysical Union Fall Meeting, San Francisco, CA, Dececember 2000.

Stanton, T.P., Turbulent stresses and shear production in bottom boundary layers in the surf zone and inner shelf, American Geophysical Union Fall Meeting., San Francisco, CA, December 2001.

THESIS DIRECTED:

Martin, S., "Vortex Ripple Morphology Using Dune2D Model," Masters Thesis, Naval Postgraduate School, March 2001.

PATENT:

Stanton, T.P., 2001. A Turbulence-Resolving Coherent Acosutic Sediment Flux Probe Device and Method For Using. U.S. Patent 6,262,942, issued 17 July 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Wave Dissipation, Shoaling Waves, Bottom Boundary Layers

UPPER OCEAN EFFECTS ON THE SURFACE HEAT BUDGET OF THE ARCTIC

Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVES: The objectives of this research are to measure the mixed layer and upper ocean heat content and heat fluxes over a one year period in the central Arctic Ocean. This work is a component of the

multidisciplinary SHEBA program which has the objectives of improving parameterizations of the coupled atmosphere-ice-ocean system in the Arctic to improve the predictive capabilities of Global Climate Models. A shorter process study focused on the role of ice keels in the surface heat balance.

SUMMARY: Between October 1997 and October 1998 the SHEBA ice camp was deployed in the Central Beaufort Sea. An automated CTD and microstructure profiler inferred turbulent fluxes from thermal microstructure measurements and the temperature/salinity structure of the upper ocean throughout a year as the ice camp drifted in response to surface wind forcing. The microstructure package was designed and built at NPS for this experiment. Analysis of the upper ocean salinity structure has revealed evidence of very significant ice melting in the last few seasons, and a paper describing this result has been published in GRL. A thesis has been completed during investigating the potential of double diffusive fluxes to net heat fluxes in areas with strong density-compensated interleaving. A paper describing the upper ocean structure and comparisons with historical data has been submitted to JGR. Techniques to improve thermal dissipation rates in the presence of strong interleaving is being developed exploiting the dual microthermistors deployed on the microstructure profiling package. This method is reducing noise levels in the vertical flux estimates which otherwise result in over-estimates of pycnocline fluxes. A unique, self contained portable ocean heat, salt and momentum flux instrument developed at NPS was deployed in an ice keel study in March 1998. This data set is being used with other SHEBA investigators to assess the role of ice keels in enhancing pycnocline entrainment.

THESIS DIREECTED:

Lamb, D.R., "Heat Fluxes Associated with Intrusions During the SHEBA Ice Station Drift," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Mixed Layer, Polar Oceans, Mixed Layer Dynamics

DETERMINATION AND ANALYSIS OF MODEL/DATA COVARIANCE FIELDS FOR ASSIMILATION PURPOSES

Robin Tokmakian, Research Assistant Professor
Department of Oceanography
Sponsors: Office of Naval Research

OBJECTIVE: Short term (several months) project to examine the errors within a high resolution model which is a candidate hindcast ocean simulation for initializing ocean prediction models. Results are contained within a draft paper to be submitted in early 2002.

SUMMARY: A comparative wavelet analysis of a 0.1 degree Parallel Ocean Program (POP) simulation of the North Atlantic with coincident in situ measurements of sea surface height (SSH) and temperature.is used to examine the realism of the high frequency signals (less than a year) of the surface variability. Along the coast, the analysis shows that the modeled simulated fields of SSH are very realistic with the correlations to tide gauge measurements on the order of 0.8. The wavelet spectra show that the model replicates the observations frequency space. Comparisons to temperatures made with NOAA buoys north and south of the Gulf Stream shows that, while not replicating the location of mesoscale features all the time, the model's energy in the strong mesoscale regions compares fairly well. Due to the nature of Topex/Poseidon (T/P) sampling that requires large areal averages and because of the model's spontaneous eddy field, the evaluation of the simulation is less conclusive. The model does show similarities to the T/P data at high latitudes where the sampling of the instrument is denser. Spatially, there are similarities between the model and observations of the areas where spectral bands have a dominant signal and the amplitude of that signal.

PUBLICATIONS:

R. Tokmakian and McClean, J., How realistic is the high frequency signal of a 0.1 degree resolution ocean model? *Journal of Geophysical Research*, to be submitted.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Ocean Modeling, Ocean Currents, Ocean Variability, Assimilation

INTERANNUAL TO DECADAL OCEAN VARIABILITY AND PREDICTABILITY

Robin Tokmakian, Research Assistant Professor
Department of Oceanography
Sponsors: National Aeronautics and Space Administration

OBJECTIVE: To understand the intrinsic interannual to decadal variability of an ocean hindcast model at a resolution of 0.25 degree resolution and to evaluate the realism of that variability with respect to satellite observations. A further objective is to investigate how surface fields measured from satellites can be used to understand the variability in the subsurface layers of the ocean.

SUMMARY: Partial completion of analysis of 0.25 degree resolution ocean model and associated satellite data. Completed and submitted first of two papers related to the realism of the low frequency variability of the ocean within the model with respect to altimeter and other satellite data.

Quantitative comparisons of a 0.25 degree resolution ocean model forced with high frequency momentum, heat, and freshwater fluxes) with tide gauges and altimeter data shows the simulation produces realistic ocean circulation for large regions of the ocean. The model output is further analyzed to quantify the contribution the surface forcing makes on the low frequency variability seen in the model and altimeter data and to understand what influence the subsurface layers have on the variability of sea surface height. At low frequencies, greater than 1.5 years, only the heat flux makes significant contribution to the SSH variability, and perhaps, the Ekman pumping in a few particular areas in the Northeast Pacific, off of Nova Scotia, and in western Pacific tropical region. The influence of the steric and lower parts of the water column to the total signal is described for both the low and interannual periods. At the low frequencies, it is the dynamics within the ocean itself, rather than any local forcing that is largely determining the variability of the SSH measurements. The salinity variability, in addition to the temperature changes, also has significant influence on the SSH signal at high latitudes and in the tropical Atlantic. Last, examples are given which show how the SSH could be used to monitor the circulation of the oceans.

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DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Ocean Modeling, Ocean Currents, Ocean Variability

BEDFORM DYNAMICS AND MINE BURIAL

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Sponsor: Office of Naval Research

OBJECTIVES: The focus of the initial year of this project has been on the development of a framework for the problem and exploration of that framework with initial data sets.

SUMMARY: As a bedform migrates past a mine, the mine will fall to the low point of the bedform trough before subsequently being buried by the passage of the following bedform crest. Thus, the statistics of mine burial are determined by the statistics of bed variability and the mine burial problem reduces to a problem of understanding the time evolution of the bottom profile envelope. If we define the bottom profile as $h(x, \tau)$, and the profile envelope as spanning from $h_{min}(x, \tau)$ to $h_{max}(x, \tau)$, then mines can sink to h_{min} and can feasibly be covered at any time by an envelope thickness, $D_{max}(x, \tau)=h_{max} - h_{min}$. ($\tau$ denotes a time scale of slow evolution). When a mine is first seeded ($\tau=0$), the envelope will have zero thickness. However, as megaripples, sand bars or any other profile features form and migrate, the thickness of the profile will grow with time in a way that depends on the overlying wave and current fields. If a mine has a vertical scale W (perhaps the diameter of a cylinder), then complete burial is possible once D_{max} exceeds W. At any subsequent time, the probability of burial depends on the statistics of $D = h - h_{min}$ as the bottom fluctuates through this envelope.

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DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Nearshore, Waves, Surf, Currents, Morphology

MEGARIPPLES IN THE SURF-ZONE

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Sponsor: National Science Foundation

OBJECTIVE: The objective is to measure and model the development of small-scale bedforms (megaripples) in the shallow ocean.

SUMMARY: Bedforms occur frequently on barred beaches and are highly variable, both spatially and temporally. However, their distribution and variability are poorly understood. A better understanding of bedforms in the nearshore would be valuable for interpretation of sedimentary sequences in the geologic record and for estimating seafloor roughness and resulting friction factors when predicting wave energy dissipation, nearshore current generation, sediment transport, and the resulting bathymetric change. Unique observations of bedforms were made using an array of sonar altimeters mounted on an amphibious surveying vehicle. The surveying vehicle (WESP), has a large footprint (10 m), and is designed to measure the large-scale bathymetry (e.g., sand bars). The altimeters have a footprint of about 6cm and are sampled at 48 Hz. After being corrected for the motion of the vehicle on which they are mounted, they produce closely spaced profiles with vertical and cross-shore resolution of about 5 cm and alongshore resolution of about 40 cm. Thus the altimeters are capable of measuring bedforms which the large surveying vehicles cannot resolve. During COAST3D, surveys were made of a 500 x 1000 m area approximately weekly. In general, roughness is greatest in shallow water and decreases offshore. However the spatial distribution of roughness is patchy and the temporal variability is high. The observed high temporal and spatial variability in shallow water is likely owing to the variability of waves and currents, sediment grain size distributions

and the large-scale nearshore morphology. These forcing mechanisms are being investigated. In addition, these observations of seafloor roughness and its distribution will be compared for two different beaches using data acquired during the SandyDuck and COAST3D nearshore field experiments (near Duck, NC USA, September-October 1997 and Egmond aan Zee, The Netherlands, October-November 1998, respectively) to further illucidate the important forcing mechanisms for bedforms in the nearshore.

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DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Near Shore, Waves, Surf

NEARSHORE WAVE AND SEDIMENT PROCESSES

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Sponsor: Office of Naval Research

OBJECTIVE: Predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the near shore given the offshore wave conditions.

SUMMARY: Data acquired during the SandyDuck and Steep Beach nearshore experiments are being analyzed compared with models developed under this program and in collaboration with other groups. During these experiments, the vertical distributions throughout the water column of 3-component mean, wave-induced and turbulent velocities, bubbles, sediment concentrations were measured. The 3-component velocity field was measured every 5 cm over the bottom 1 m with a downward looking 1.3 MHZ bistatic coherent acoustic Doppler velocimeter (1.6 cm resolution at 48 Hz) and in the upper water column with a 300 KHz upward looking coherent bistatic acoustic Doppler velocimeter every 8 cm (8 cm resolution at 48 Hz). In addition, the vertical distribution of the horizontal velocities were measured with an array of 8 electromagnetic current meters. The small-scale morphology, which acts as hydraulic roughness for the mean flows and perturbs the velocity-sediment fields, was measured with newly developed, in-house, x-y scanning altimeter. The primary mechanism for changes in moment flux which drives the nearshore dynamics is due to the dissipation of breaking waves, the processes of which are only poorly understood. To improve our understanding of breaking waves, the dissipation associated with bubble injection and depth of bubble penetration were measured with the two acoustic systems (1.2 MHZ looking down and 300KHz looking up) and with a 3 m vertical array of 8 conductivity cells. An important component of the cross-shore sediment flux is due to the cross-shore mean flow (undertow), which is forced by wave set-up/down; the set-up was measured with an array of 8 pressure sensors. Undertow is an integral measure of the turbulent Reynold's stresses and wave radiation stresses and acts as a check for the detailed velocity measurements.

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DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Nearshore, Waves, Surf

ACOUSTIC RANGING DURING FLEET BATLE EXPERIMENT ECHO (FBE-E) USING THE INVERSE BETA (IB) ALGORITHM

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Sponsor: Naval Postgraduate School

OBJECTIVE: The primary objective is to evaluate a new methodology to use EW emissions from surface ships collected from national sensors and first relate their tracks to those generated from acoustic arrays. Then an acoustic ranging technique for passive arrays, called Inverse Beta (IB), is evaluated on FBE-E data.

SUMMARY: National sensor data, resident in the GALE Lite database, has been collected and analyzed from ships participating in FBE-E off southern California during 13-14 April 1999. Simultaneous acoustic broadband data were recorded from several Advance Deployable System (ADS) arrays. Ship tracks were constructed from the EW emissions captured in the GALE Lite database and related to the time-bearing plots generated by the acoustic data. Achievements included a nearly perfect correlation of the EW and acoustic intercepts, establishing the target range for the acoustic sensors, and identification of surface ships as military (by name) or merchant.

DoD KEY TECHNOLOGY AREA: Battlefield Environments

KEYWORDS: FBE-E, GALE Lite, Acoustic Ranging, ADS

UNDERSTANDING ANTARCTIC SEA ICE AND OCEAN INTERACTIONS USING HIGH RESOLUTION GLOBAL ICE-OCEAN MODELS

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Albert J. Semtner, Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The overall objective is to advance the science of environmental prediction using highly parallel models of the global ocean and southern hemisphere sea ice. The variability and predictability of climatic variations as well as longer term climatic change are being examined.

SUMMARY: Considerable progress was made in simulating and understanding the "Antarctic Circumpolar Wave." The high-resolution coupled model of ocean and ice reveals subsurface aspects not previously available from limited observations in the Southern Ocean. Examination of slightly coarser resolution results from the Parallel Climate Model with an active atmosphere show correctly propagating signal of the ACW in both atmosphere and ocean -- a first for climate models. Results were published in the *Annals of Glaciology*, Vol. 33, pp. 539-544, 2001.

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DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Battlespace Environments

KEYWORDS: Sea Ice, Southern Ocean, Numerical Modeling, Supercomputing

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Reniers, A., E.B. Thornton, T. Stanton and J. MacMahan, Modeling of Rip-Currents during RIPEX, American Geophysical Union Fall Meeting, San Francisco, CA, December 2001.

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MEETING ABSTRACTS

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PATENTS

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DEPARTMENT OF PHYSICS

WILLIAM MAIER
CHAIR

PHYSICS

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:

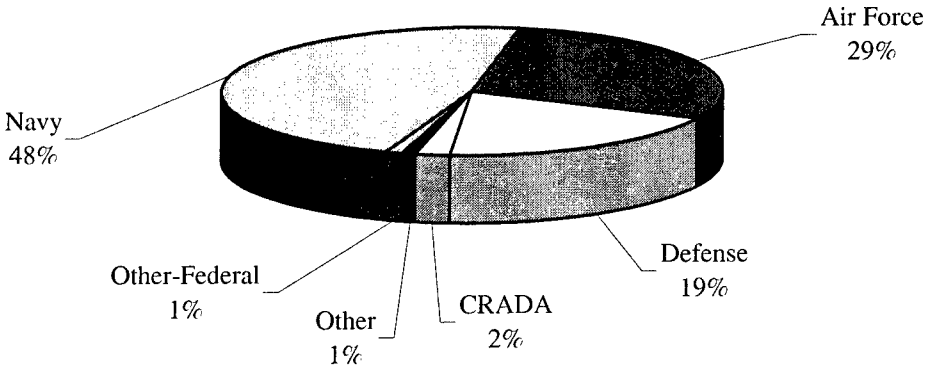
- Lawrence Livermore National Laboratory Chair Professor
- Engineering Acoustics Chair Professor

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.

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:



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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, ehick 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, Artifical Physics, Orientation, Agents, Cinfiguration

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 or 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.

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.

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.

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

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

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 elevate-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^2 at 21-23°C is estimated to fall to as low as 10^{-18} 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 quadropole 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.

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 Professer
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.

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.

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 Acosutics 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

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 Hammburg, April 2001.

DoD KEY TECHNOLOGY AREAS: Other (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 Countermeasures)

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

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.

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

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

Li, T.B. Wang, C.-P. Chang, 2001: Theories on the tropospheric biennial oscillation: A review. *Dynamics of Atmospheric. and Oceanic Circulations and Climate*, eds: M. Wang et al, Chinese Academy of Sciences, China Meteorological Press, Beijing, pp. 872.

DEPARTMENT OF OCEANOGRAPHY

MARY L. BATTEEN
CHAIR

OCEANOGRAPHY

OVERVIEW:

The Department of Oceanography has developed a broad research program focused on physical oceanography to meet the anticipated future needs of the Navy. Our basic research themes are the development of scientific capabilities to measure, analyze, and forecast fields of littoral ocean variables, which occur in association with synoptic/mesoscale processes over limited regional temporal domains. The areas of emphasis include coastal and nearshore ocean dynamics, air-sea interaction phenomena and boundary currents. Regions of interest include the polar seas, coastal ocean regions and strategic straits of the world.

Our applied research themes are the application of analyses and forecasts of upper ocean synoptic/mesoscale variability to Naval operations. Areas of emphasis include the impact of littoral processes, eddies and boundary currents on ocean surveillance systems, the effect of coastal ocean response to storms on acoustic propagation and ambient noise and the impact that the wave climate exerts on nearshore processes and beach character as it pertains to mine/mine countermeasure and amphibious warfare.

These research themes require the development of numerical ocean prediction and synoptic oceanography capabilities. They are achieved through employment of modern dynamical and mathematical principles, numerical and statistical methods, computational and graphical facilities, and in-situ and remote sensing observations.

CURRICULA SERVED:

- Meteorology and Oceanography
- Operational Oceanography
- Oceanography
- Undersea Warfare
- Space Systems Operations
- Space Systems Engineering

DEGREES GRANTED:

- Master of Science in Meteorology and Physical Oceanography
- Master of Science in Physical Oceanography
- Doctor of Philosophy

RESEARCH THRUSTS:

- Acoustical Oceanography:
  Professor Ching-Sang Chiu, Emeritus Professor Robert Bourke, Assistant Professor Arthur Parsons, Research Professor James Wislon
- Air-Sea Interaction and Ocean Turbulence:
  Professor Roland Garwood, Research Associate Professor Tim Stanton, Professor Peter Chu, Professor Le Ly
- Coastal and Nearshore Oceanography:
  Associate Professor Jeff Paduan, Distinguished Professor Ed Thornton, Associate Professor Thomas Herbers, Research Assistant Professor Edith Gallagher, Assistant Professor Pierre Poulain, Professor Curt Collins, Research Professor Steve Ramp, Research Associate Professor Leslie Rosenfeld
- Numerical Prediction and Data Assimilation:
  Associate Professor Mary Batteen, Professor Bert Semtner, Research Associate Professor Julie McClean, Research Assistant Professor Robin Tokmakian, Research Assistant Professor Ramsey Harcourt, Research Associate Professor Wieslaw Maslowski, Assistant Professor Pierre Poulain, Senior Lecturer Arlene Guest, Research Associate Professor Le Ly

- GI&S and Navigation: Research Professor James Clynch, Assistant Professor Arthur Parsons
- Polar Oceanography:
  Research Associate Professor Wieslaw Maslowski, Research Assistant Professor Yuxia Zhang, Emeritus Professor Robert Bourke, Professor Roland Garwood, Research Assistant Professor Ramsey Harcourt

RESEARCH FACILITIES:

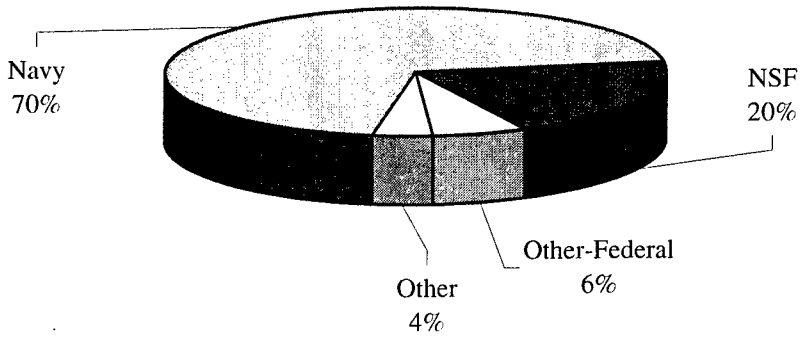
- Research Vessel *Point Sur*
- Ocean Acoustic Observatory at Point Sur
- Computer Graphics Laboratory
- Moored Equipment Laboratory
- Calibration Laboratory
- Tactical Environmental Support Laboratory

RESEARCH CHAIR:

- Office of Naval Research Chair in Arctic Marine Science

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 Oceanography is provided below:



Size of Program: $3858K

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ONR CHAIR IN ARCTIC MARINE SCIENCE

Robert H. Bourke, Professor Emeritus
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The Chief of Naval Research has established at the Naval Postgraduate School a Chair in Arctic Marine Science. The objectives of the Chair are to foster oceanographic research in the Arctic, acquaint naval officer students with Arctic problems, reduce results of pure research to operational usage, and publicize Navy interest in the Arctic.

SUMMARY: Professor Bourke served as administrator of the Chair handling such details as selecting Chair candidates, writing IPAs and proposals and setting up visits and seminars for the Chair incumbent.

Professor Ursula Schauer from the Alfred Wegener Institute for Polar and Marine Research was the Chairholder during FY01. While at NPS Dr. Schauer analyzed data and drafted papers based on two data sets acquired in Fram Strait. She examined three years of high resolution current meter and temperature data from buoys spread across Fram Strait. This data provided an initial sense of the variability of the volume and heat flux into and out of the Arctic Ocean. Based on a series of observations carried out through a number of European programs conducted in the 1990s, she determined the flux of Atlantic Water to the Arctic Ocean and its modifications enroute along two pathways leading to the central Arctic Ocean. She also provided several lectures to the Polar Oceanography course and gave a series of seminars to the Department faculty.

A search was conducted for the follow-on Chairholder. Prof. Mark A. Johnson from the University of Alaska has been selected. He will be in residence from October 2001 to September 2002 and will conduct work on modeling the Arctic atmosphere, sea ice and ocean as a coupled system to understand climatic changes.

DoD KEY TECHNOLOGY AREAS: Battlefield Environments

KEYWORDS: Arctic Ocean, Fram Strait, Barents Sea, Atlantic Water

COUPLED OCEAN ACOUSTICS AND PHYSICAL OCEANOGRAPHY OBSERVATIONS IN THE SOUTH CHINA SEA: THE NPS ACOUSTIC COMPONENT

Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: This effort is part of a large, international program called the Asian Sea International Acoustic Experiment (ASIAEX). In collaboration and coordination with other U.S. and Asia investigators participating in ASIAEX, comprehensive measurements and analysis were being carried out of the different oceanographic factors affecting low frequency (< 600 Hz) acoustic propagation in a shelfbreak region in the Northeastern South China Sea (SCS). Specifically, the NPS acoustic research objectives are: 1) To understand the physics, variability and predictability of low-frequency sound pulse propagation along and across the NE SCS shelfbreak, including the dependence on frequency, source depth and path orientation, and the relations to water-column, bathymetric and sub-bottom structures. 2) To expand the acoustic knowledge acquired from previous shelf-slope experiments including shelfbreak PRIMER and SWARM, with added emphases on the horizontal properties of the sound field. 3) To investigate the advantages and disadvantages of conducting shallow-water tomography using higher-frequency (> 400 Hz) transmissions. 4) To formulate and test a phase or time-based modal tomography inverse method for joint estimations of the water-column and sediment properties.

SUMMARY: The main field program was a huge success. It was executed from 25 April to 27 May 2001 by approximately 20 principal investigators from three different countries, U.S., Taiwan and Singapore, using three Taiwanese research vessels *FISHERIES RESEARCHER 1* (FR1), *OCEAN RESEARCHER 1* (OR1) and *OCEAN RESEARCHER 3* (OR3). The simultaneous, high-resolution observations of the acoustic propagation characteristics and water column properties was accomplished by a combination of

moored and shipboard observations. The NPS team was primarily involved in the preparation, design, deployment, and recovery of the moored network. This network consisted of a total of 27 environmental moorings and 6 acoustic moorings stretching the pre-designed across and along-shelf mooring lines. The centerpiece of this observational network was an L-shaped hydrophone array that was put together by WHOI and NPS. This listening array consisted of 32 hydrophones spanning 472 m along the bottom and 16 hydrophones moored vertically in the water column. These hydrophones sampled at 3.2 kHz continuously for three weeks and collected 600 gigabytes of data. These data are still being quality controlled, backed up and distributed to the participating institutions. The processing and analysis of the entire acoustic data set, in conjunction with the oceanographic data, is currently underway with goal to understand the influences of inherent ocean variability on acoustic propagation, coherence and predictability.

PUBLICATIONS:

Chiu, C.-S., S. R. Ramp and J.F. Lynch, The ASIAEX 2000 preliminary experiment in the East China Sea (ECS), *Proceedings of the Fifth International Conference in Theoretical and Computational Acoustics*, Beijing, China, 2001. (Invited Paper)

Colosi J.A., J.F. Lynch, R.C. Beardsley, G. Gawarkiewicz, C.-S. Chiu and A. Scotti, Observations of nonlinear internal waves on the New England continental shelf during summer shelfbreak, *PRIMER*, *Journal of Geophysical Research*, 106(C5), 9587-9601, 2001.

PRESENTATION:

Chiu, C.-S., Sound speed fluctuation statistics in the South China Sea, Asian Sea International Acoustics Experiment (ASIAEX) Workshop, Maui, HI, 31 October–2 November 2001.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments

KEYWORDS: Littoral, Acoustics, Shelfbreak

DETERMINATION OF THE DETECTION AND CLASSIFICATION PROBABILITIES AND RANGE LIMITS OF INEXPENSIVE ACOUSTIC SENSORS AND DATA PROCESSING TECHNIQUES FOR MONITORING ODONTOCETI WHALES

Ching-Sang Chiu, Professor
Curtis A. Collins, Professor
Department of Oceanography
Sponsor: Chief of Naval Operations (N45)

OBJECTIVE: To realistically determine the effectiveness of simple and cost-effective sonar systems (sensors and processing techniques) for monitoring toothed whales (odontoceti) in areas with diameters smaller than a few kilometers. Sensors to be evaluated include sonobuoy array, short-aperture suspended arrays, and bottom-mounted arrays. Processing methods to be considered include Energy detectors for transient signals, a matched-signal method employing a fast, analytic propagation model for localization and signal deverberation over a small area, correlation classifiers and wavelet based methods.

SUMMARY: The approach is to design and conduct controlled at-sea experiments to derive quantitative performance measures: probability of detection and classification, probability of false detection and classification, and range limits.

A digital audio library of available odontocete calls was collected and representative calls were selected for playback experiments at sea. Two at sea deployments were conducted in July and November 2001. The selected whale signals were transmitted from both G34 and J9 transducers to SSQ-57B sonobuoys at ranges of 1-5 km. The experiment was conducted in both shallow (<300m) and deep (>1500m) water depths with the source and receivers varied between 30 and 125m. Each call was played at

ten-minute intervals for three hours at each source depth to study the statistical variation during the analysis.

DoD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

KEYWORDS: Marine Mammal, Passive Acoustic Detection

UNCERTAINTIES AND INTERDISCIPLINARY TRANSFERS THROUGH THE END-TO-END SYSTEM (UNITES)

Ching-Sang Chiu, Professor
Department of Oceanography
Sponsors: Office of Naval Research

OBJECTIVE: This effort is part of a multi-institutional team effort to capture uncertainty in the common tactical picture. The team's name is UNITES, which stands for UNcertainties and Interdisciplinary Transfers through the End-to-End System. The UNITES team, with expertise spanning the ocean environment, underwater acoustics and tactical sonar systems, consists of a total of twelve principal investigators from nine different organizations including Harvard University (HU), the Naval Postgraduate School (NPS), and the OASIS, Inc. The NPS component in the UNITES team's paradigm to solve the interdisciplinary, end-to-end problem has two objectives: 1) To characterize acoustic prediction uncertainties, including their connections to the uncertainties in the ocean and geo-acoustic parameter estimates. 2) To forecast and improve acoustic baselines and their uncertainties in a data-assimilation framework involving coupled ocean and acoustic state variables.

SUMMARY: The research focuses on a shelfbreak environment, encompassing the outer continental shelf and the continental slope, where the physical oceanography, specifically the shelfbreak front, internal tides and internal solitary waves, play a significant role in introducing acoustic prediction uncertainty at multiple time and space scales. The acoustic prediction uncertainty is further complicated by the variable bathymetry and inhomogeneous sediment properties as the water-column variability shifts the insonified bottom locations from time to time. In close collaboration with HU and based on Error Subspace Statistical Estimation (ESSE), a methodology for the modeling and prediction of coupled ocean physics and acoustic uncertainties was developed and tested with the Shelfbreak PRIMER data. The test was a case study of the linkage between ocean mesoscale uncertainties and acoustic wavefield uncertainties in a slope-to-shelf transmission across the MAB shelfbreak front.

PUBLICATION:

Lermusiaux, P.F.J., C.-S. Chiu and A.R. Robinson, Modeling uncertainties in the prediction of the acoustic wavefield in a shelfbeak environment, *Proceedings of the Fifth International Conference in Theoretical and Computational Acoustics*, Beijing, China, 2001. (Invited Paper)

PRESENTATION:

Lermusiaux, P.F.J., C.-S. Chiu and A.R. Robinson, Coupled physical-acoustical data assimilation and prediction of uncertainties in a shelfbreak environment, Thirty third International Liège Colloquium on Ocean Dynamics, Liège, Belgium, 7-11 May 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Environmental Uncertainties, Acoustic Uncertainties, Sonar Performance

MINE IMPACT BURIAL SENSITIVITY STUDY

Peter C. Chu, Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVES: This proposal is to assess current Navy's Impact Burial Prediction Model (IBPM). The most recent version of the IBPM (i.e., IMPACT25) will be integrated and it will be used to compare predicted burial against a descriptive mapping from grain size to impact burial developed by NAVOCEANO. Core data will be obtained from NAVOCEANO for this study. This comparison will help assess the need for improvements to the IBPM and whether the NAVOCEANO mapping is adequate for Naval operations use. This is a continuation of a series of recent NPS thesis studies on mine burial.

SUMMARY: A series of mine drop experiments with different sizes of model mines were conducted at NPS and Naval Surface Warfare Center to obtain a complete dataset for depicting the mine movement in the water column:

Analysis on the data collected from the Mine Impact Burial Experiment (MIBEX). This experiment was designed to collect synchronous mine impact burial and environmental data. The experiment was conducted on 23 May 2000 at the site of the Monterey Inner Shelf Observatory (MISO) off of Del Monte Beach in Monterey Bay (Smith 2000). The model mine is a 55 gallon drum filled with sand to give it a uniform density. During the experiment, 17 gravity cores were obtained. The oceanic environmental parameters were recorded at MISO. The burial depth was measured by the divers. The mine impact and environmental (water column and sediment) data were analyzed in FY01.

Mine Drop Experiment (MIDEX) at the NPS swimming pool. MIDEX basically consisted of dropping each of three right cylinders into the water where each drop was recorded underwater from two viewpoints. The controlled parameters for each drop were: center of mass position (COM), initial velocity (Vinit), drop angle and the ratio of mine's length to diameter.

A synchronized data set of ocean environment (including waves, currents, and bottom shear strength) and mine burial depth was established on the base of the Mine Impact Burial Experiment (MIBEX). A technical report depicting this dataset was published by NPS and widely distributed into the minewarfare community.

Mine Drop Experiment (MIDEX) was conducted in June 2001 at the NPS swimming pool with 1/20 scale model mines. Around 500 mine drops were completed with different mine parameters (L/D, COM) and drop conditions (angle and velocity). Upon completion of the drop phase, the video from each camera was converted to digital format and a dataset for mine movement in the water column was established.

Mine test experiment at Carderock was completed. LCDR Ashely Evans participated the experiment and started the data analysis.

The hydrodynamic system depicting the movement of rigid body (such as mine) in the water column has been established on the base of balance of momentum and moment of momentum. This system consists of nine nonlinear equations. Among them, three equations depict the acceleration of the center of mass; three equations depict the moment of momentum balance, and three equations predict the three Euler angles of the mine. This hydrodynamic system does not have analytical solutions due to the nonlinearity. A numerical model is being built to solve the problem.

Workshop was conducted on ONR Expert System Program on Mine Impact Burial Prediction at NPS on 10 January 2001. The MIBEX dataset was transferred to the ONR Expert System group.

The dynamic system (nine nonlinear equations) for the mine movement has the potential impact on the nonlinear dynamics. The hydrodynamics of mine impact in water column can be applied to a general scientific problem of the fluid-rigid body interaction including stability and chaotic motion.

The datasets obtained from three consecutive experiments, MIBEX, MIDEX, and Mine testing at Carderock, will impact the scientific and Naval minewarfare communities on the mine movement in the water column.

The results obtained from this project are transferred to the Naval Oceanographic Office, COMINEWARCOM, and the ONR Mine Impact Burial Prediction group. Two major weaknesses in water phase of IMPACT25 (tumbling of mine and no moment of momentum balance) are well accepted by the minewarfare community. The datasets collected from MIBEX and MIDEX will greatly impact on the development of an accurate Mine Impact Burial Prediction Model. The data were also used for

development of the Expert System for Mine Impact Burial at the Applied Physics Laboratory of the John Hopkins University and the Environmental Sciences Department of the University of Virginia.

PUBLICATIONS:

Chu, P.C., T.B. Smith and S.D. Haeger, "Mine Burial Impact Prediction Experiment," Naval Postgraduate School Technical Report, NPS-IJWA-01-007, pp.161, 2001.

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PRESENTATIONS:

Chu, P.C., Mine impact burial model and data comparison, ONR Expert Systems Modeling Workshop, Monterey, CA, 10 January 2001.

Chu, P.C., Hydrodynamics of mine impact burial, ONR Impact Burial Annual Workshop, La Jolla, CA, 15-17 January 2002.

THESES DIRECTED:

Gilles, A., "Hydrodynamics of Mine Movements," Masters Thesis, Naval Postgraduate School, September 2001.

Cintron, C., "Verification of an Operational Acoustic Model (CASS-GRAB) in Mine Hunting Application," Masters Thesis, Naval Postgraduate School, March 2001.

DoD TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Modeling and Simulation

KEYWORDS: Mine Impact Burial, Shear Strength, Moment of Momentum, Sediment Type

SOUTH CHINA SEA AND JAPAN SEA MODELING

Peter C. Chu, Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVES: This is a multi-year project. Under the current sponsorship the following research has been completed: an optimization scheme for determining open boundary conditions, high-order difference schemes for reducing sigma coordinate error at abrupt topography, a statistical model for determining thermohaline variability, and a parametric model for obtaining physical characteristics (SST, mixed layer depth, thermocline depth, thermocline strength, etc.) from vertical profiles. It is proposed to incorporate these new techniques into the South China Sea prediction system (POM) and to expand the modeling effort into a coastal air-ocean coupled model.

SUMMARY: (1) A coastal atmosphere-ocean coupled system (CAOCS) is developed. The oceanic component consists of the Princeton Ocean Model (POM) with 20 km horizontal resolution and 23 sigma levels conforming to a realistic bottom topography. The atmospheric component consists of a recent version of the regional climate model (RegCM2) with 40 km horizontal resolution and 16 vertical levels. The CAOCS model was integrated for a month from 1 May 1995. The initial conditions for the atmosphere are the ECMWF analyses, and for the ocean are the model output from a forty four months' run of the stand-alone POM model forced by climatological monthly mean wind stresses, and restoring type surface salt and heat. The CAOCS model agrees well with an extensive airborne expendable bathythermograph (AXBT) survey of the South China Sea (SCS) conducted in May 1995, and shows the capability of simulating the SCS multi-eddy structure in May 1995.

(2) A variational P-vector method was developed to invert the velocity field. The GDEM for the JES was built up on historical (1930-1997) 136,509 temperature and 52,572 salinity profiles. The climatological mean and seasonal variability of the current systems are well inverted especially the Tsushima Warm Current (TWC) and its bifurcation, the East Korean Warm Current\ (EKWC), the Japan Nearshore Branch (JNB), the confluence of the EKWC and the North Korean Cold Current (NKCC) near the Korean coast and flows northeastward along the subpolar front, and a mesoscale anticyclonic eddy in the Ulleng/Tsushima Basin. Furthermore, this method has the capability to invert flow reasonably well across the shallow straits such at the Tsushima/Korea, Tsugaru, and Soya Straits. The GDEM temperature and salinity and the inverted velocity fields provide a balanced initial fields for JES numerical modeling and simulation.

(3) A geometric model has been developed for determination of subsurface thermal structure from satellite sea surface temperature observations. Based on a layered structure of temperature fields (mixed-layer, thermocline, and lower layers), the parametric model transforms a vertical profile into several parameters: sea surface temperature (SST), mixed layer depth (MLD), thermocline bottom depth (TBD), thermocline temperature gradient (TTG), and deep layer stratification (DLS). These parameters vary on different time scales: SST and MLD on scales of minutes to hours, TBD and TTG on months to seasons, and DLS on an even longer time scale. If the long time scale parameters such as TBD, TTD, and DLS are known (or given by climatological values), the degree of freedom of a vertical profile fitted by the model reduces to one: SST. When SST is observed, we may invert MLD, and, in turn, the vertical temperature profile with the known long time scale parameters: TBD, TTG, and DLS.

(4) The South China Sea warm-core/cool-core eddies were identified using the Navy's MOODS data as well as the National Meteorological Center (NCEP) sea surface temperature (SST) fields (1982-94).

(5) The sigma-coordinate, pressure gradient error depends on the choice of difference schemes. By choosing an optimal scheme, we may reduce the error in a great deal without increasing the horizontal resolution. Several high-order schemes were developed.

(6) Haney-type surface thermal boundary conditions connect net downward surface heat flux to air/sea temperature difference (gradient-type condition) or to climate/synoptic sea temperature difference (restoring-type condition). On the basis of cross-correlation and variance analyses on the net downward surface heat flux and air/sea temperature data from global coupled atmosphere-ocean model, we obtain the following results: (i) The restoring-type conditions do not represent the surface thermal forcing anywhere in the world oceans. (ii) For the equatorial and subtropical oceans, the gradient-type conditions are not good approximations for the surface thermal forcing. (iii) For the middle and high latitudes away from coasts, the gradient-type conditions are good approximation for the surface thermal forcing.

PUBLICATIONS:

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PRESENTATIONS:

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Chu, P.C., Yellow Sea/East China Sea thermohaline variability, Pacific Conference International, San Francisco, CA, 8-11 July 2001.

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Chu, P.C. and L. Ivanov, First-passage for determination of model predictability with uncertain initial errors, American Geophysical Union Spring Meeting, Boston, MA, 28 May-1 June 2001.

Chu, P.C. and L. Ivanov, Backward Fokker-Planck equation for determination of model predictability with uncertain initial errors, Thirteenth Conference on Atmospheric and Oceanic Fluid Dynamics, American Meteorological Society, Breckenridge, CO, 4-8 June 2001.

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Chu, P.C. and C.W. Fan, A finite volume ocean model, Seventh International Conference on Estuarine and Coastal Modeling (ECM 7), St. Petersburg, FL, 5-8 November 2001.

Chu, P.C. and L.M. Ivanov, Reconstruction of Gulf of Mexico circulation from drift buoy data, Fourth Conference on Coastal Meteorology and Oceanography, American Meteorological Society, St. Petersburg, FL, 5-8 November 2001.

Chu, P.C. and R.F. Li, Determination of isopycnal surface circulation from hydrographic data, Fourth Conference on Coastal Meteorology and Oceanography, American Meteorological Society, St. Petersburg, FL, 5-8 November 2001.

Chu, P.C., Scaling and fractals in ocean mixed layer, American Geophysical Union Fall Meeting, San Francisco, CA, 10-14 December 2001.

THESES DIRECTED:

Roth, M., "A Coastal Air-Ocean Coupled System for the East Asian Marginal Seas," Masters Thesis, Naval Postgraduate School, September 2001.

DoD TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Modeling and Simulation

KEYWORDS: P-vector, Geostrophic Velocity, Beta-Spiral, Inverse Method, Primitive Equation Model, Turbulence Closure, High-Order Difference Schemes, Predictability Density Function

THEORETICAL ANALYSIS OF PREDICTABILITY AND SENSITIVITY FOR OCEAN CIRCULATION MODELS

Peter C. Chu, Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVES: The objective of this project is to develop a spectral approach for the assimilation of drifting buoy data into eddy-resolution regional circulation models. The approach is based on the analysis of the principle components of Fisher's Information Matrix (FIM) constructed from a knowledge of the model, area and sources of the bias of Eulerian statistics calculated by Lagrangian data. To obtain a relation between the Eulerian and Lagrangian statistics a model of buoy dynamics is used in statistically inhomogeneous non-Gaussian eddy velocity field with a finite correlation time. It's demonstrated that the approach is applicable for known and unknown open boundary conditions and is robust to the variations of sizes of observation samplings. The knowledge of FIM allows to formulate requirements to properties of assimilation procedure (assimilation strategy) and quality of Lagrangian data to achieve the maximum improving of model now/forecast skill. The approach is examined through the assimilation of the synthetic and real drifter data into the regional oceanographic models of the Gulf of Mexico and Japan/East Sea.

SUMMARY: A new theoretical approach was developed to quantitatively evaluate predictability of regional and basin-scale eddy-resolving numerical models and applied this approach to analyze the forecast skill of Princeton Ocean Model. The quantitative criterion for estimating forecast skill was also est ablished.

The planned work was completely finished. First, the special iteration technique was developed on the base of Ivanov et al. (1994) for analytical estimations. Second, a new power law was found for the second kind of predictability applying our approach to verify numerical model results by the drifter buoy data. Such a power law allows the reformulation of the predictability theory and to introduce a new concept of "extreme prediction." Third, the statistics of the extreme predictions may considerably improve the prediction skill of ocean models. Fourth, several quantitative measures of the prediction skill have been suggested and examined. All these measures are based on the definition of the first passage time. The usefulness of the first-passage time is demonstrated in various ocean models. Fifth, a special procedure was developed for reconstructing circulation from sparse and noisy data in domains with open boundaries. The technique was successfully used to the nowcast of daily circulation on the Louisiana-Texas shelf reproduced from the SCULP-1 drifter data and LATEX moored current meter data.

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PRESENTATIONS:

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Chu, P.C., L.M. Ivanov, T.P. Korzhova, T.M. Margolina and O.V. Melnichenko, Reconstruction of ocean currents from sparse and noisy data in an open domain, Joint Assembles of the International Association for Physical Sciences of the Oceans, International Association for Biological Oceanography, Mar del Plata, Argentina, 22-26 October 2001.

Chu, P.C. and L.M. Ivanov, Reconstruction of Gulf of Mexico circulation from drift buoy data. Fourth Conference on Coastal Meteorology and Oceanography, American Meteorological Society, St. Petersburg, FL, 5-8 November 2001.

Chu, P.C., Scaling and fractals in ocean mixed layer, American Geophysical Union Fall Meeting, San Francisco, CA, 10-14 December 2001.

DoD TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Modeling and Simulation

KEYWORDS: Valid Prediction Period, First-Passage Time, Fokker-Planck Equation, Tolerance Level, Error Growth

GPS ANTARCTIC LANDING SYSTEM: LANDING SYSTEMS COMMITTEE STUDIES

James R. Clynch, Research Professor
Department of Oceanography
Sponsor: Space and Naval Warfare Systems Center - Charleston

OBJECTIVE: The aircraft landing system at the U.S. bases in Antarctica must be replaced in the next few years. GPS is the primary candidate system for use in this remote site. There are several special features about the local environment in polar latitudes that must be studied and validated before flight safety can be assured. Dr. Clynch offers advise to the Antarctic Landing Systems committee as a member and their scientific advisor.

SUMMARY: The technical capability of a differential GPS system to meet the landing requirements in Antarctic has been demonstrated in an ongoing effort over five years. During 2001 the effort focused on following the FAA specification development process for the Local Area Augmentation System (LAAS). During this year the FAA LAAS specification can to closure, at least on a first edition. Test systems are in place in the U.S. and vendors are taking orders. The efforts this year also included investigations of the effects of radio frequency interference on GPS and GPS landing systems.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronics, Sensors

KEYWORDS: GPS, Aircraft Landing Systems

GPS FIELD TEST QUICK LOOK SOFTWARE UPGRADE

James R. Clynch, Research Professor
Department of Oceanography
Sponsor: Naval Surface Warfare Center - Dahlgren Division

OBJECTIVE: To update GPS data quality software to run with newer GPS formats.

SUMMARY: NSWC and NPS have cooperated on GPS experiments and data analysis for several years. Some of their routinely used software originated at NPS. This software does not function with the implementation of new formats by some of the GPS manufacturers. New versions of the software now functions with the hardware NSWC uses in field experiments.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: GPS, Differential GPS

CENTRAL CALIFORNIA HYDROGRAPHIC SURVEYS

Curtis A. Collins, Professor
Department of Oceanography
Sponsor: San Jose State University Foundation and Scripps Institute of Oceanography

OBJECTIVE: The objective of this project are to extend the hydrographic data base off the U.S. West Coast for the Naval Oceanographic Office and to improve the understanding of the California Current and its associated upwelling ecosystem.

SUMMARY: Hydrographic surveys of Central California waters were conducted in May and December, 2001 by the R/V *New Horizon* and the R/V *Point Sur*, respectively. Surveys were based upon the California Cooperative Fisheries Investigations station pattern and ranged from Point Reyes to Point Sur and offshore to a distance of about 160 km. Three 25-hr time series stations were also sampled, two in the Gulf of the Farallons and one in Monterey Bay. Biological and chemical sampling was included along the hydrographic line that extends offshore from Moss Landing (Line 67). December data collection efforts were limited by poor weather conditions and were not as extensive as those in May.

PUBLICATIONS:

Castro, C.G., T.R. Baumgartner, S. Bograd, R. Castro, F.P. Chavez, C.A. Collins, R. Durazo, J. Garcia, G. Gaxiola-Castro, T. Hayward, A. Huyer, R. Lynn, A.S. Mascarenhas, M.R.D. Robert, R.L. Smith, P.A. Wheeler and F.A. Whitney (2002). Introduction to "The 1997-8 El Niño Atlas of Oceanographic Conditions along the West Coast of North America (23(N-50(N)," *Progress in Oceanography*, in press.

Castro, C.G., R. Michisaki, T.R. Baumgartner, S. Bobrad, R. Castro, F.P. Chavez, C.A. Collins, R. Durazo, J. Garcia, G. Gaxiola-Castro, T. Hayward, A. Huyer, R. Lynn, A.S. Mascarenhas, M.R.D. Robert, R.L. Smith, P.A. Wheeler and F.A. Whitney, *The 1997-8 El Niño Atlas of Oceanographic Conditions along the West Coast of North America (23(N-50(N),* NPS Technical Report NPS-OC-01-002, 5 pp & CD, 2001.

Castro, C.G., C.A. Collins, P. Walz, J.T. Pennington, R.P. Michisaki, G. Friederich and F.P. Chavez, Chemical variability during El Niño 1997-8 off Central California, *Progress in Oceanography*, 2001, in press.

Chavez, F.P., J.T. Pennington, C.G. Castro, J.P. Ryan, R.M. Michisaki, B. Schlining, P. Walz, K.R.,Buck, A. McPhadyen and C.A. Collins, Biological and chemical consequences of the 1997-98 El Niño in central California waters, *Progress in Oceanography*, 2002, in press.

Collins, C.A., C.G. Castro, H. Asanuma, T. Rago, S.-K. Han, R. Durazo and F. Chavez, Changes in the hydrography of Central California Waters associated with the 1997-8 El Niño, *Progress in Oceanography*, 2001, in press.

Durazo, R., et. al., "State of the California Current," CalCOFI Reports, pp., 2001.

Wilkerson, F.P., Dugdale, R.C., Marchi, A. and Collins, C.A., Hydrography, nutrients and chlorophyll measured during El Niño, La Niña compared to normal years in the Gulf of the Farallones, CA, *Progress in Oceanography*, 2001, in press.

THESIS DIRECTED:

Moore, C. "Seasonal Variability of Extratopical North Pacific Wind Stress, Ekman Pumping, and Sverdrup Transport," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Hydrographic Data, Ocean Currents, El Niño

OCEAN CURRENTS AND SEDIMENT TRAP MEAUSREMENTS

Curtis A. Collins, Professor
Department of Oceanography
Sponsor: Monterey Bay Aquarium Research Institute

OBJECTIVE: The objective of this program is to measure the deep currents and vertical sediment fluxes below the relatively well-sampled surface ocean waters offshore of Monterey Bay.

SUMMARY: Ocean current and sediment trap measurements were continued at site S2 (36-40N, 122-22W) in 2001. The intermediate mooring was recovered and replaced on January 25, 2001 and August 16, 2001. Current and sediment trap measurements were made at depths of 300 and 1200 m.

PUBLICATIONS:

Castro, C.G., Chavez, F.P. and Collins, C.A. Role of the California undercurrent in the export of denitrified waters from the eastern tropical North Pacific, *Global Biogeochemical Cycles*, 15, 819-830, 2001.

THESIS DIRECTED:

Gabriel, C.L., "The Physical Description of Bottom Sediments near Sur Ridge, California," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Ocean Currents, Sediment Flux

NONHYDROSTATIC MODELING OF WEST FLORIDA SHELF FLOW AND TRACERS

Roland W. Garwood, Jr., Professor
Ramsey Harcourt, Research Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective is to calculate nonstationary three-dimensional solutions for the turbulent nonhydrostatic flow regime on the West Florida shelf using Large-Eddy Simulation. These solutions will be used to help explain the three-dimensional optical properties of the water column by understanding the behavior of tracers and drifters deployed during field experiments.

SUMMARY: In collaboration with Kent Fanning and John Walsh of the University of South Florida the OPBL Laboratory of the Naval Postgraduate School is conducting numerical solutions for the turbulent nonhydrostatic flow regime on the West Florida shelf using Large-Eddy Simulation. These solutions are for times and locations appropriate to explain the optical properties of the water column by understanding the behavior of tracers and drifters deployed during field experiments with AUVs (autonomous underwater vehicles). Animated GIFS of the turbulent boundary layer on the West Florida shelf, which have been produced with the assistance of NRC Postdoctoral Associate, Pascale Lherminier, are used to display the three-dimensional unsteady evolution of the turbulent fluxes and turbulent kinetic energy attributable to the combined forcing by the winds and the geostrophic current.

PUBLICATIONS:

Ly, L.N. and R.W. Garwood, Jr., An ocean circulation model with surface wave parameterization, *Applied Numerical Mathematics*, Vol. 40, pp. 351-366, 2001.

CONFERENCE PRESENTATION:

Garwood, R.W., Jr, "Structure and temporal evolution of turbulent boundary layers in the Florida shelf," HYCODE Workshop, St. Petersburg Beach, FL, 8-10 February 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Sensors, Modeling and Simulation, Other (Oceanography)

KEYWORDS: Air-Sea Interactions, Tracers, Lagrangian Drifters

POLAR SEA CONVECTIVE INSTABILITIES

Roland W. Garwood, Jr., Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The major scientific objective of this five-year study has been to understand the convective response of the coupled ocean mixed layer-ice system to the passage of atmospheric storms. The connection between the earth's atmosphere and its deep oceans begins with the cooling and sinking of seawater in the polar seas. This convection process is the 'engine' of the 'conveyer belt' of global-scale oceanic circulation for renewal and replacement of the large volume of deep water that spreads across the earth's connected ocean basins. This project has sought to explain the previously poorly understood process of oceanic deep convection that occurs very rapidly (order of hours to days) and on a very small (order of a few kilometers) scale in comparison with the space and time scales of the conveyor belt (order of tens of thousands of kilometers and hundreds of years, respectively).

SUMMARY: The most significant results include the theoretical prediction and numerical verification of a new class of convective instabilities. These instabilities, which arise due to the nonlinear relationship of seawater density upon salinity, temperature, and pressure, produce vertical convection in the polar oceans that physically may resemble vertical convection by cumulus clouds in the tropical atmosphere. As for the

cumulus convection in the atmosphere, this oceanic convection may produce some of the largest vertical velocities in the world's oceans.

These results will guide future work on how to better include the effects of oceanic deep convection in coupled oceanic-atmospheric climate and global change predictions. The results will also suggest where, when and how to design field experiments to monitor and detect deep convection and signs of climate change. Tools that enabled success in this research include: (1) Large-Eddy Simulation (LES) on high-performance computers, which is the numerical modeling of the full equations of motion without the limiting assumptions usually applied in oceanic circulation modeling; (2) Verification of LES computer predictions with actual oceanic observations from Lagrangian drifters.

Major findings are:

1. The comparison between one-dimensional mixed-layer and three-dimensional LES models is leading to improved parameterization of entrainment and convection for eventual inclusion in basin-scale OGCMs.
2. LES results for conditional instabilities are confirmation and improvements of our understanding of the probable nature of parcel and layer instabilities in the ocean.
3. Large-scale horizontal gradients in temperature and salinity generate mesoscale cyclones and anti-cyclones that modify the deep convection caused by local surface cooling.
4. Thermobaricity has been found to generate conditional instabilities of two kinds: i) parcel, and ii) layer. A third phenomenon, 'thermobaric stability' has been identified that can enable lenses and filaments of T-S density-compensated water to remain stable and unmixed as it is advected laterally and from the polar sea basins and onto the shelf.
5. Biases in Motion of Drifters in Convection. Earlier Large-Eddy Simulations (LES) showed that isobaric floats would tend to accumulate in convergence zones. Since these convergence zones are associated with local mean vertical velocity, the isobaric drifters were predicted to experience a mean vertical velocity, even if there were no vertical flow horizontally averaged at that depth. Modeling of isobaric floats by LES for the winter of 1994 in the Greenland Sea and of 1996 in the Labrador Sea show that the bias in drifter-observed vertical velocity measurements bears also on the estimation of variances and vertical fluxes derived from drifter-observed temperature and salinity. Quantification of this bias is possible at least in the lower part of the mixed layer, provided that the horizontal divergence field is known.
6. Ice Model Added to LES. The study of 1996 float data in the Greenland Sea and of ANZFLUX hydrographic profiles in the Weddell Sea led us to add a thermodynamic sea ice layer on top of the LES. All the second order non-linearities of the seawater equation of state (as thermobaricity and cabbelling) were included in order to better understand the relative effect of each. It is seen that cabbelling delays the growth of penetrative thermobaric plumes and favors the formation of an intermediate layer often observed in the Wedell Sea, but still unexplained.
7. Thermobaricity and Maintenance of Sensible Heat Polynyas. A critical mixed layer depth for free-convection under polynyas was predicted. This is potentially very significant for deep water formation beneath sensible heat polynyas such as the Wedell Polynya as well as near-freezing open water in the Greenland Sea and other marginal ice zones Wherever warmer and saltier intermediate water underlies polar sea surface mixed layers, entrainment of the deeper water into the surface mixed layer convects heat upward that may melt ice and/or inhibit further freezing. Forced convection by wind stirring may lead to such melting, especially if the mixed layer is shallow and free convection from surface cooling is not large. For deeper mixed layers, however, the turbulent kinetic energy (TKE) budget for a mixed layer of depth h shows that the TKE that leads to deep free convection and entrainment is most readily generated by strong upward surface buoyancy flux associated free convection induced by surface cooling. The classical TKE model having a linear equation of state predicts that the upward entrainment heat flux into the bottom of the such deep mixed layers generally will be less than the upward surface heat flux into the atmosphere and/or ice. Hence, surface cooling usually has been expected to predominate over entrainment warming, with the net result of freezing or mixed-layer cooling until freezing does occur. In a nonclassical free convection model demonstrated for the first time, the TKE budget is corrected to include thermobaricity, the increase in the thermal expansion of seawater with increased pressure. This correction to buoyancy and buoyancy flux from a proper equation of state shows clearly the relationship between depth of mixing and the increase in entrainment due to thermobaricity. In particular, a critical depth (HCR) of mixing is predicted for which any surface

cooling will lead to melting of ice and subsequent net warming of the surface layer. Mixed layers deeper than this critical depth (h> HCR) will melt ice and maintain polynyas regardless of the intensity of surface cooling. Such super-critical mixed layers may be initiated either by wind-aided forced convection, or by advection. Near-critical cases including the Weddell polynya will be examined in future research.

PUBLICATIONS:

Lherminier, P., R.R. Harcourt, R.W. Garwood, Jr. and J.-C. Gascard, Interpretation of mean vertical velocities measured by isobaric floats during deep convection events, *Journal of Marine Systems*, 29, 221-237, 2001.

Harcourt, R.R., E.L. Steffan, E.L., Garwood, R.W., Jr. and D'Asaro, E.A., Fully Lagrangian floats in Labrador sea deep convection: comparison of numerical and experimental results, *Journal of Physical Oceanography*, in press, 2001.

PRESENTATION:

Garwood, R.W., Jr., Critical mixed layer depth for maintaining convective polynyas, International Polynyas Symposium, Quebec City, Canada, 9-13 September 2001.

DoD KEY TECHNOLOGY AREA: Battlespace Environments, Environmental Quality, Sensors, Modeling and Simulation, Other (Oceanography)

KEYWORDS: Air-Sea Interactions, Ocean Convection

THERMOBARICITY: A COLLABORATIVE WEBSITE

Arlene Guest, Senior Lecturer
Department of Oceanography
Sponsor: McPhee Research Company

OBJECTIVE: The goal of this project is to expedite the sharing and exchange of scientific about thermobaricity and to facilitate the planning and design of observation and modeling studies of thermobaricity in a collaborative web environment.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Thermobaricity, Collaborative, WEB, Environments

DATA ENHANCED MODELING OF SEA AND SWELL ON THE CONTINENTAL SHELF

William C. O'Reilly, Research Assistant Professor
Thomas H. C. Herbers, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To develop and test improved wave propagation and data assimilation methods that are compatible with the coastal wave prediction model SWAN and applicable to a wide range of geographic settings.

SUMMARY: Data assimilation methods are under development for the coastal wave prediction model SWAN. Currently SWAN and similar regional wave prediction models are nested within the global wave prediction model WAM. A drawback of this approach is that initialization errors (e.g., errors in WAM predictions owing to uncertainties in the wind field and inaccuracies in the propagation of waves over large distances) can seriously degrade the coastal model predictions. In this project new methods are

implemented to enhance the quality of coastal wave predictions through the assimilation of in-situ (e.g. directional wave buoys) and remotely sensed (e.g., airborne and satellite radar systems) wave data collected at the offshore boundaries or within the model domain. This project is an ongoing collaboration with scientists from NRL-SSC.

PRESENTATIONS:

Wingeart, K., W.C. O'Reilly, T.H.C. Herbers, P.A. Wittmann, R.E. Jensen and H.L. Tolman, Validation of operational global wave prediction models with spectral buoy data, *Proceedings Fourth International Symposium on Ocean Wave Measurement and Analysis*, American Society of Civil Engineers, 2001, in press.

THESIS DIRECTED:

Wingeart, K., "Validation of Operational Global Wave Prediction Models with Spectral Buoy Data," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality, Battlespace Environments

KEYWORDS: Wave and Surf Forecasts, Data Assimilation

IMPROVED PARAMETERIZATIONS OF TRIAD AND QUARTET INTERACTIONS IN SPECTRAL WIND-WAVE MODELS

Thomas H. C. Herbers, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this project is to improve the representation of nonlinear wave-wave interactions in operational wave prediction models.

SUMMARY: It is well known that nonlinear wave-wave interactions are poorly represented in current operational wave prediction models (e.g., WAM, SWAN). In this project a team of scientists from the Naval Postgraduate School, the Army Corps of Engineers, David Taylor Model Basin, and Alkyon Hydraulic Consultancy and Research, are evaluating the shortcomings of existing models and developing and testing new approximations. A numerically efficient technique for computing the energy exchanges between four wave components in quartet interaction was validated through comparisons with exact numerical calculations.

DoD KEY TECHNOLOGY AREA: Environmental Quality, Battlespace Environments

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Continental Shelf, Beach

NEARSHORE CANYON EXPERIMENT (NCEX)

Thomas H. C. Herbers, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this research is to understand the effect of complex continental-shelf bathymetry on surface gravity waves and on the breaking-wave-driven circulation onshore of the irregular bathymetry.

SUMMARY: Abrupt shelf bathymetry can cause dramatic alongshore variations in waves, resulting in beaches with large waves located only a few hundred meters away from beaches with small waves. These along-coast changes in wave height and direction can force complicated circulation patterns, including

alongshore flows that reverse direction across the surf zone and along the shoreline, and strong offshore-directed rip currents that may be an important mechanism for transport of water, sediment, and pollution between the surf zone and inner shelf. Models will be tested with observations of waves and currents made on the southern California coast near two steep submarine canyons. Model initial conditions (incident waves) will be acquired with a directional buoy located offshore of the canyons. The effect of the canyons on waves and wave-driven circulation will be measured with directional buoys near the canyons, and with pressure-gage and current-meter arrays deployed onshore of the canyons in 10- and 2.5-m water depths. Additional specialized arrays will be deployed to investigate wave reflection and scattering from the steep canyon walls, and cross-shore changes in surf zone circulation. Drifters will be used to estimate the location, flow speed, and offshore extent of rip currents. This project is a collaborative effort with Woods Hole Oceanographic Institution (Dr. Steve Elgar) and Scripps Institution of Oceanography (Dr. Robert T. Guza).

PUBLICATIONS:

Elgar, S., R.T. Guza, W.C. O'Reilly, B. Raubenheimer and T.H.C. Herbers, Wave energy and direction observed near a pier, *Journal of Waterway, Port, Coastal, and Ocean Engineering*, 127(1), 2-6, 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality, Battlespace Environments

KEYWORDS: Ocean Surface Waves, Surf Zone, Nearshore Processes

SURFACE GRAVITY WAVES ON THE CONTINENTAL SHELF AND BEACH

Thomas H. C. Herbers, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this project is to predict accurately the evolution of surface waves from deep water across the continental shelf to the beach.

SUMMARY: This project is focused on the effects of nonlinear wave-wave interactions and wave breaking on the evolution of wind-wave spectra across the inner continental shelf and beach. Analysis of detailed wave shoaling measurements collected during the DUCK94 and SandyDuck (1997) experiments demonstrates the important role of nonlinear triad wave-wave interactions in the surf zone energy balance. Analysis of array measurements in shallow water shows significant deviations from the linear dispersion relation for surface gravity waves. A new nonlinear dispersion relation was derived and shown to be in good agreement with the field measurements.

PUBLICATIONS:

Lentz, S., M. Carr and T.H.C. Herbers, Barotropic tides on the North Carolina shelf, *Journal of Physical Oceanography*, 31(7), 1843-1859, 2001.

Noyes, T.J., R.T. Guza, S. Elgar and T.H.C. Herbers, Comparison of methods for estimating nearshore shear wave variance, *Journal of Atmospheric Oceanic Technology*, 19(1), 136-143, 2002.

Herbers, T.H.C., S. Elgar, N.A. Sarap and R.T. Guza, Nonlinear dispersion of surface gravity waves in shallow water, *Journal of Physical Oceanography*, 2002, in press.

Sheremet, A., R.T. Guza, S. Elgar and T.H.C. Herbers, Observations of nearshore infragravity waves. Part 1: Seaward and shoreward propagating components, *Journal of Geophysical Research*, 2002, in press.

Herbers, T.H.C., M. Orzech, S. Elgar and R.T. Guza, Shoaling transformation of wave frequency-directional spectra, *Journal of Geophysical Research*, 2002, submitted.

PRESENTATIONS:

Sheremet, A., R.T. Guza, S. Elgar and T.H.C. Herbers, "Estimating infragravity wave properties from pressure-current meter array observations," *Proceedings of the Twenty Seventh International Conference on Coastal Engineering*, ed. Billy L. Edge, American Society of Civil Engineers, pp. 1476-1489, Sydney, Australia, 2001.

Lippmann, T.C., T.H.C. Herbers and E.B. Thornton, "Observations of infragravity waves in the nearshore," *Proceedings of the Fourth Coastal Dynamics Conference*, ed. E.B. Thornton, American Society of Civil Engineers, pp. 55-61, Lund, Sweden, 2001.

THESES DIRECTED:

Balolong, M.O., "Validation of a Stochastic Boussinesq Model for Wave Spectra Transformation in the Surf Zone," Masters Thesis, Naval Postgraduate School, June 2001.

Ruth, D., "A Nonlinear Wave Shoaling Model for Alongshore Varying Bathymetry," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality, Battlespace Environments

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Continental Shelf

WAVE EVOLUTION ON THE CONTINENTAL SHELF

Thomas H. C. Herbers, Associate Professor
Department of Oceanography
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The main objective of this project is to evaluate the energy balance of wind-generated waves in shallow water.

SUMMARY: Six surface-following directional wave buoys and a coherent array of pressure sensors were deployed on the North Carolina continental shelf as part of the ONR SHoaling Waves EXperiment (SHOWEX) to investigate the transformation of wind waves and swell across a continental shelf. High-quality data was collected through a wide range of conditions including Hurricanes Floyd, Gert, and Irene with maximum wave heights in excess of 10 m. Detailed bottom information was collected during three cruises including sediment samples, sidescan surveys of small-scale bottom roughness and high resolution bathymetry. Analysis of the SHOWEX observations by Ph.D. student Fabrice Ardhuin using a new numerical model for wave evolution across the continental shelf has demonstrated the important role of seabed ripples in the attenuation of swell. The measurements will also be used to verify theoretical predictions of nonlinear spectral energy transfers and estimate wave energy losses resulting from whitecaps.

PUBLICATIONS:

Ardhuin, F., T.H.C. Herbers and W.C. O'Reilly, A hybrid Eulerian-Lagrangian model for spectral wave evolution with application to bottom friction on the continental shelf, *Journal of Physical Oceanography*, 31(6), 1498-1516, 2001.

Ardhuin, F. and T.H.C. Herbers, Bragg scattering of random surface gravity waves by irregular sea bed topography, *Journal of Fluid Mechanics*, 451, 1-33, 2002.

Ardhuin, F., T.G. Drake and T.H.C. Herbers, Observations of wave-generated vortex ripples on the North Carolina continental shelf, *Journal of Geophysical Research*, 2002, in press.

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.

PUBLICATIONS:

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

JOURNAL PAPERS

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.

Colson, W.B., "Short-Wavelength Free Electron Lasers in 2000," *Nuclear Instruments and Methods in Physics Research A475*, pp. 397, 2001.

Denardo, B., Pringle, L., DeGrace, C. and McGuire, M., "When do Bubbles Cause a Floating Body to Sink?" *American Journal of Physics*, Vol. 69, pp. 1064-1072, 2001.

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.

Shipley, M.N., Stokely, J., Smith, K.B. and Larraza, A., "Laboratory Experiments of Time-Reversed Acoustics Applied to Sonar in Shallow Water Waveguides," *Journal of the Acoustical Society of America*, Vol. 110, pp. 2708, 2001.

Smith, K.B., "Convergence, Stability and Variability of Shallow Water Acoustic Predictions Using a Split-Step Fourier Parabolic Equation Model," *Journal of Computational Acoustics*, Vol. 9, pp. 243-285, 2001.

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.

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.

Thomson, R.W. Jr., 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.

Tolstoy, A., Smith, K.B. and Maltsev, N., "The SWAM'99 Workshop - An Overview," *Journal of Computational Acoustics*, Vol. 9, pp. 1-16, 2001.

Tucholski, E., Larraza, A. and Droege, M., "Resonant Sonic Spectroscopic Studies of Aoerogels Solids," *Journal of the Acoustical Society of America*, Vol. 110, pp. 2628, 2001.

Tucholski, E. and Larraza, A., "Measurements of Acoustic Einstein-Hoft Drag on Objects Undergoing Volume Oscillations," *Journal of the Acoustical Society of America*, Vol. 110, pp. 2652, 2001.

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.

CONFERENCE PAPERS

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

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

Larraza, A. and Tucholski, E., "Separation Techniques Using High Intensity Sound," V Encontro de Tecnologia em Acústica Submarina, Instituto de Pesquisas de Marina, Rio de Janeiro, Brazil, 21-23 November 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.

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.

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. .

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.

Therrien, C.W., Kouteas, S.D. and Smith, K.B., "Time Delay Estimation Using a Signal Subspace Model," *Proceedings of the Thirty Fourth Asilomar Conference on Signals, Systems, and Computers,* pp. 832-836, Monterey, CA, 29-31 October 2000.

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.

CONFERENCE 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 Intersubb and Transitions in Quantum Wells, Asilomar, CA, 10-14 September 2001.

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

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

Colson, W.B., "MW FEL Oscillator Considerations'" Workshop on Free-Electron Laser Development for Naval Applications, Newport News, VA, June 2001.

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

Colson, W.B., "Simulations of the 100kW TJNAF FEL Using a Short Rayleigh Length," 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.

SPACE SYSTEMS ACADEMIC GROUP

RUDOLF PANHOLZER
CHAIR

SPACE SYSTEMS

OVERVIEW:

The Space Systems Academic Group (SSAG) along with eight academic departments is an integral part of the Graduate School of Engineering and Applied Sciences. As an interdisciplinary association of professors it provides direction and guidance for two curricula: Space Systems Engineering and Space Systems Operations.

Officer students in the Space Systems curricula fulfill degree requirements for a Master of Science in the department of their choice or in a specialized Engineering Science. A space-oriented thesis is mandatory as well as course work to fulfill the requirements of a space billet. Officer graduates are prepared to manage the technical aspects of a space system life cycle including design, development, installation, and maintenance of spacecraft, space payloads, supporting ground stations, terminals, and C3 connectivity.

The SSAG serves as the focal point for all space-related research performed at NPS. A major goal is to couple NPS space research efforts with the graduate education of military officers. This is typically accomplished through space-related thesis research in several areas and includes small satellite projects created specifically as an educational tool for officer students. The SSAG oversees classified and unclassified student involvement in research activities and helps facilitate their placement in follow-on tours.

CURRICULA SERVED:

- Space Systems Operations
- Space Systems Engineering

DEGREES GRANTED:

- Master of Science in Space Systems Operations
- Master of Science in Astronautical Engineering
- Master of Science in Electrical Engineering
- Master of Science in Mechanical Engineering
- Master of Science in Applied Physics

RESEARCH THRUSTS:

- Military Applications for Space
- Space Reconnaissance and Remote Sensing
- Radiation Hardened Electronics for Space
- Design, Construction and Launching of Small Satellites
- Classified (SCI level) Research
- Satellite Communications Systems
- Military Space Systems and Architectures

RESEARCH CHAIRS:

- Navy Space Technology Program Chair
- Navy Tactical Exploration of National Capabilities (TENCAP) Space Chair
- Space Systems Academic Chair
- NASA Michael J. Smith Space Systems Chair
- National Reconnaissance Office Chair
- Lockheed Martin Space and Missile Operations Chair

RESEARCH CENTERS:

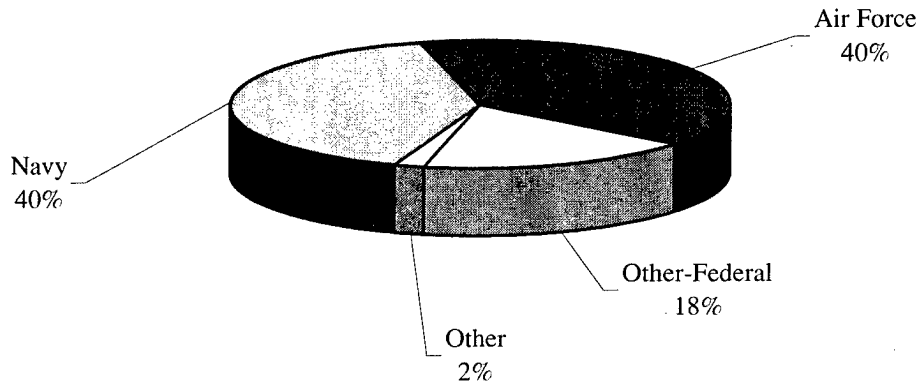
- Spacecraft Research and Design Center
- Center for Reconnaissance Research
- Center for Radiation Hardened Electronics
- Center for Cryptologic Research

RESEARCH FACILITIES:

- Open Site EMI/EMC Facility
- Satellite Ground Station Facility
- Space Warfare Computer Laboratory
- FLTSATCOM Satellite Operations
- Simulation and Test Laboratory
- Spacecraft Attitude Dynamics and Control Laboratory
- Spacecraft Environmental Simulation an Test Laboratory
- Radiation Effects Laboratory
- Solar Simulation Facility
- NPS-AFRL Optical Relay Spacecraft Laboratory
- Flash X-Ray Facility
- Electron Linear Accelerator
- Small Satellite Test and Development Laboratory
- Smart Structures Laboratory

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 Space Systems Academic Group is provided below:



Size of Program: $1059K

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FERROELECTRICITY NEWSLETTER

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this quarterly publication is to provide the ferroelectric research community a means to keep informed about conferences, symposia, workshops and related activities in the field of integrated ferroelectrics. This newsletter offers summaries and titles of recently published and presented papers in addition to individual contributions by engineers and scientists in the field of ferroelectrics.

SUMMARY: A total of four Ferroelectricity Newsletters (FENL) were generated in hard copy format as well as made available on the web: http://www.sp.nps.navy.mil/projects/ferro/ferro.html

Input for the FENL was obtained from various sources, including open literature, proceedings of conferences, symposia, workshops and though individual contacts with scientists. In addition, the PI co-chaired the Thirteenth International Symposium on Integrated Ferroelectrics, a rich source of material for the FENL.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Integrated Ferroelectrics, Thin Films, Piezoelectric Materials, Pyroelectric Materials, Dielectric Properties, Non-volatile Memories

MAGNETIC TORQUE RODS FOR NAVAL POSTGRADUATE SCHOOL NPSat1

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this proposal is to fund the acquisition of magnetic torque rods for the attitude control subsystem of the NPSat1 Micro-satellite which is part of the small satellite design program under the NPS Space Systems academic group.

SUMMARY: NPSAT1 will implement a novel, low-cost three-axis attitude control subsystem (ACS) which utilizes only magnetic torque rods for actuators, a three-axis magnetometer as a sensor input, and on-board orbit determination through software algorithms to achieve pointing accuracy less than ±5° in each axis. Funding under this proposal supports the acquisition of the flight magnetic torque rods for NPSat1.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Magnetic Torque Rods

NAVAL POSTGRADUATE SCHOOL SPACECRAFT ARCHITECTURE AND TECHNOLOGY DEMONSTRATION SATELLITE

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this proposal is to fund the development of the NPSat1 Micro-satellite which is part of the small satellite design program under the NPS Space Systems Academic Group.

SUMMARY: NPSat1 supports the educational efforts in the Space Systems Academic Group while marrying research goals in small satellite technology development. NPSat1 is manifested on the Space Test Program (STP) MLV-05 mission due to launch in January 2006 on a Delta IV. A number of experiments will be flown from the National Reconnaissance Office, Naval Research Laboratory, and from

within the Naval Postgraduate School. Technology demonstration experiments aboard NPSat1 include on-orbit testing of triple-junction solar cells, micro-electromechanical systems (MEMS) rate sensors, lithium-ion and lithium-ion polymer batteries, ferroelectric memory, and a PC-compatible command and data handling architecture. Two science experiments onboard NPSat1 are provided by the Naval Research Laboratory: the coherent electromagnetic radio tomography (CERTO) beacon and a Langmuir probe.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Lithium-Ion Polymer Battery, Space Systems Engineering, Micro-satellite, Command and Data Handling, Ionospheric Tomography, Communications Networking

NAVAL SPACE SYSTEMS ACADEMIC CHAIR

Rudolf Panholzer, Professor
Charles M. Racoosin, Naval Space Systems Academic Chair
Space Systems Academic Group
Sponsor: Naval Space Command

OBJECTIVE: Incumbents of the Naval Space Systems academic chair engage in instruction and research and act as consultants in their area of specialization to students and faculty of the Naval Postgraduate School.

SUMMARY: This proposal funded the Naval Space Systems Academic Chair. The incumbent taught courses in Military Satellite Communications, Space Technology and Applications; Space Mission Analysis and Design; Space Mission Architecting; and Launch Systems selection. He acted as a thesis advisor for the following topics:

1) Using UAVs to supplement satellites for communications and signals intelligence missions,
2) Using UAVs as switching nodes for Battle Group intranets,
3) Joint Space Training,
4) Using Global Broadcast Service to deliver large meteorological products,
5) Using GPS more realistically in campaign-level simulations and wargames,
6) Using a wireless/satellite LAN/WAN in remote combat.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles, Space Vehicles, Command, Control and Communications, Computing and Software, Manpower, Personnel and Training, Sensors, Modeling and Simulation

KEYWORDS: Aerospace Propulsion, Air Vehicles, Space Vehicles, Communications, Computing, Software, Sensors, Modeling and Simulation

SPACE SYSTEMS OPERATIONS EXPERIENCE TOURS

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: Naval Space Command

OBJECTIVE: The objective of this proposal is to fund Space Systems Academic Group (SSAG) students thesis research projects, directed studies, and space operations experience tours.

SUMMARY: This proposal funded experience tour travel by the Space Systems Operations and Space Systems Engineering students to various government and commercial facilities and organizations. Sites visited this year were: NRO, DARPA, NRL, NRL Blossom Point, ADF Buckley AFB, Lockheed-Martin Littleton, Colorado, U.S. Space Command, Johnson Space Center, Kennedy Space Center, and AFTAC Patrick AFB.

Additionally, this proposal funded thesis specific travel such as: 1) to the ISIOC school in Colorado Springs, 2) a space power conference, 3) a blue force tracking/combat ID conference, 4) various trips to Washington D.C./NASA Dryden to visit thesis sponsors.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles, Command, Control and Communications, Computing and Software, Electronic Warfare, Manpower, Personnel and Training, Sensors, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: Aerospace Propulsion, Air Vehicles, Space Vehicles, Communications, Computing and Software, Sensors, Modeling and Simulation

SPACE SYSTEMS STUDENTS THESIS RESEARCH PROJECTS, DIRECTED STUDIES, AND SPACE ENGINEERING EXPERIENCE TOUR

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this proposal is to fund Space Systems Academic Group (SSAG) students thesis research projects, directed studies, and space engineering experience tours.

SUMMARY: Funding under this proposal directly supports the Space Systems Engineering curriculum. Specific areas of support include the engineering staff labor and the Space Systems Engineers experience tours. The engineering staff provides continuity and area expertise in the Small Satellite Design Studies Program as well as general thesis research support. The experience tour program includes six weeks of travel of which two weeks is in conjunction with officer students in the Space Systems Operations curriculum on a cadre tour of government, Department of Defense, and industry space facilities. Four weeks of the experience tour are set aside for off-site thesis research at a host facility.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles, Command, Control and Communications, Computing and Software, Electronic Warfare, Manpower, Personnel and Training, Sensors, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: Aerospace Propulsion, Air Vehicles, Space Vehicles, Communications, Computing and Software, Sensors, Modeling and Simulation

FIRST PRINCIPLES PREDICTION OF X-RAY IMPULSE

Donald v. Wadsworth, Senior Lecturer
Space Systems Academic Group
Sponsor: Strategic Systems Programs Office

OBJECTIVE: Develop a first principle technique for predicting the impulse induced on selected surfaces by an X-ray burst in space. Validate the theoretical model by comparing predictions with available underground test data and other experimental data.

SUMMARY: This research project (currently in its second year) supports the Trident Stockpile-to-Target Stewardship program. The multi-year objectives are: (i) collect and archive key data (reports and interviews) relevant to predicting the vulnerability of an RB aeroshell to an x-ray burst in space, (ii) compare the capability of existing physics-based models (finite-element hydro codes and radiation deposition codes) to predict blow-off impulse and damage to various RB composite materials, (iii) modify a selected code to improve fidelity, (iv) validate the modified code against existing test data (UGT and AGT) and, if needed, plan and execute new tests using existing facilities (flash x-ray and surface loading). This is a collaborative effort involving faculty in the NPS Space Systems Academic Group and the departments of Physics, Mechanical Engineering, and Electrical and Computer Engineering. Two Navy master's degree candidates are performing thesis research in support of this effort. Significant consulting

support is being provided by the DoE National Laboratories, as well as Defense Threat Reduction Agency, and DoD contractors.

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

KEYWORDS: X-ray, Weapons Effects, Nuclear Weapons

SPACE SYSTEMS ACADEMIC GROUP

2001
Faculty Publications and Presentations

There are no publications included in the Space Systems Academic Group section. Publications for professors associated with Space Systems are listed in each professor's home department.

GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

DOUGLAS A. BROOK
DEAN

GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

MISSION:

The mission of the Graduate School of Business and Public Policy is:

- To Improve the managerial capabilities and leadership qualities of US and international officers and government civilians through graduate education, research, and professional service.
- To develop students' abilities to analyze, think critically, and take intelligent action so they can more effectively carry out their professional responsibilities, and lead their organizations in complex, and sometimes life-threatening, environment.
- To conduct research that supports military decision-making, problem solving, and policy setting, improves administrative processes and organizational effectiveness, contributes knowledge to academic disciplines, and advances the mission of graduate education.
- To provide professional expertise that supports the development of the Naval Postgraduate School, the Departments of Navy and Defense, and other branches of Government, as well as our professional and academic organizations.

RESEARCH MISSION:

Faculty research is an important component of the Graduate School of Business and Public Policy's mission. As such, the school strives to "conduct research that supports military decision making, problem solving, and policy setting, improves administrative processes and organizational effectiveness, contributes knowledge to academic disciplines, and advances the mission of graduate education."

The research program is integrated to the greatest possible extent with the educational process. Students are encouraged to participate in faculty projects, and faculty research results are typically incorporated in classroom instruction.

CURRICULA SERVED:

The Graduate School of Business and Public Policy has primary responsibility for five graduate degrees. The largest degree program is a group of curricula in the Master of Science in Management. The MS in Management program was converted to Defense-focused MBA program in 2001 with the following curricular concentration areas:

- Acquisition Management
- Logistics Management
- Manpower Management
- Financial Management
- Information Management
- Defense Management

Distance learning graduate programs offered by the Graduate School of Business and Public Policy include: Contract Management and Program Management (for Department of Defense civilians at designated off-site locations), which award a Master of Science in Contract Management and a Master of Science in Program Management, respectively; and Leadership Education and Development program (for Company Commanders at the U.S. Naval Academy), which awards a Master of Science in Human Resources Management.

The School's graduate programs achieved the distinction of being one of only two graduate management programs in the country earning dual accreditation by AACSB-the Association to Advance Collegiate Schools of Business and NASPAA-the National Association of Schools of Public Affairs and Administration.

RESEARCH THRUSTS:

The primary goal of the school's research program is to provide the Navy and DoD with the capability of managing defense organizations and programs efficiently and effectively. Therefore, the objective of the school's research effort is to apply existing knowledge base in support of resource utilization decisions,

to develop new concepts or theory if no such knowledge base exist to support the policy/decision making process, to enhance the relevance of the school's instructional programs, and to involve the students through their thesis or application project work in enhancing their decision making capability.

While concepts and knowledge base are generally divided into different functional areas or disciplines, actual resource utilization decisions or policies often require multi-disciplinary efforts. Therefore, in addition to pursuing functional area research in those disciplines with a critical mass of faculty, the thrust of the school's research program is to conduct cooperative interdisciplinary research in areas where the school is in a strong position to become a leading force in research. It also places the school in a strong position to assist defense policy makers, since it allows for a coordinated, broad-based program under "one roof"—where researchers from diverse fields can share information and findings in a unified and truly systematic fashion.

The faculty of the Graduate School of Business and Public Policy are drawn from a wide variety of academic disciplines in business and public sector management. The diverse, multidisciplinary character of the faculty is reflected in the breadth and depth of issues addressed by faculty research, which has historically been concentrated in areas of interest to the Departments of Defense and Navy. Therefore, faculty research directly enriches the instructional materials used in the curricula in the school. The topics and issues can be grouped into five broad areas:

- *Acquisition and Contract Management,*
- *Logistics and Transportation Management,*
- *Financial Management,*
- *Manpower Systems Analysis,*
- *Organization, systems and Management.*

FACULTY:

The research thrusts and faculty in each of the functional areas in the Graduate School of Business and Public Policy are discussed in greater detail in the following sections.

Acquisition and Contract Management. Defense acquisition represents a process of critical importance to the military, not only to reduce taxpayer costs, but to ensure the quality and performance of today's increasingly sophisticated weapon systems. Nevertheless, negligible academic research has been applied to systematically investigate, understand, and model the acquisition process; and current innovations in this domain—such as process reengineering and acquisition reform—are uncoordinated, ad-hoc, and performed largely on a trial-and-error basis. This is the case because many acquisition policy makers and executives have little or no benefit of sound theories to rely upon.

The acquisition group's primary objective is outlined as a multidisciplinary research program, designed to address this dearth of acquisition theory. Generally, research objectives are directed at the following:

- basic theory-building research into critical questions;
- fundamental dimensionality and key attributes associated with defense acquisition; and
- exploring the integrated reengineering and reform of acquisition processes through the development of empirical models, prototyping of advanced technologies, and rigorous analysis of process innovations and regulatory reform.

This research represents seminal scholarly work in the area of defense acquisition and draws from expertise in accounting, contracting, economics, information systems, law, organizational design, public policy, and other academic disciplines. The research program also plans for contributions not only from the NPS faculty, but through collaborative research with faculty from other major universities outside DoD through the External Acquisition Research Program (EARP) initially established by Professor Mark Nissen and currently managed by Professor Ira Lewis. EARP program and projects supported can be seen at the website: http://www.nps.navy.mil/earp/.

Logistics and Transportation Management. The primary mission of the Logistics and Transportation Management group is to educate military officers and DoD civilians in state-of-the-art concepts of logistics and transportation management. Emphasis is placed on understanding both military and non-military applications, so that students will be prepared to perform effectively in a military

environment and interact efficiently with civilian contractors and suppliers. The general research perspective of the group is focused on improving DoD logistics and transportation performance as well as management effectiveness. Major research thrusts in this area include:

- DoD inventory policy;
- inventory and cycle time reduction;
- defense transportation and distribution systems;
- modeling and simulation for logistics decision support;
- reduction of manpower in aircraft and ship maintenance;
- aircraft Component Improvement Program (CIP); and
- sea-based logistics for the Navy and the Marine Corps.

Professor Kevin Gue's project developed throughput and storage system models for crossdocks and transshipment points, with particular application to sea base design in Sea Based Logistics. Professor Keebom Kang focused on using modeling and simulation method to address transportation and inventory issues. His current project addresses sea-based combat logistics of LHD amphibious attack ships. Senior Lecturer Don Eaton (RADM, USN, Ret.) Led a team of thesis students investigating the issues and concerns of aging aircraft and tactics of remediation and amelioration.

Financial Management. Research in the area of financial management has become increasingly important since the end of the Cold War, as defense organizations "downsize" and policy makers exercise renewed efforts to gain maximum utility of shrinking resources at minimum cost. The Financial Management (FM) group has identified four major functional areas as targets of opportunity for future research. These are:

- financial resource policy formulation, analysis and management;
- enterprise resource planning systems;
- financial matters of personnel entrusted with sensitive information;
- cost analysis,
- federal financial reporting and financial statement analysis.

The first of these functional areas—financial resource policy formulation, analysis, and management—covers a range of sub-areas: national defense and national security resource policy and management; resource planning, programming, budgeting, and policy under the Planning, Programming, Budgeting System; and relationships between financial management, contracting, acquisition, and other policy fields. Professors Larry Jones, Jerry McCaffery, and Richard Doyle have the expertise in this area.

Resource planning systems cover the development of systems, such activity-based management systems (ABM) and enterprise resource planning systems (ERP) capable of generating timely and reliable information for operational decisions. Professors Ken Euske continue to be involved in DoN's ERP efforts. Professor Joseph San Miguel were supported by Financial Executive Research Foundation to study the strategic impact of ERP systems.

Recent events of high profile security breach have heightened interest in the financial matter of those entrusted with sensitive information. Since 1998, Professor San Miguel has provided financial expertise to the National Security Agency, U.S. Customs, and the Central Intelligence Agency on the design and evaluation of employee financial disclosures for identifying unexplained affluence and financial stress. His current project applied financial analysis techniques to live data obtained from federal employees in positions of national security in attempt to highlight abnormality.

The research area of cost analysis covers the following: weapon systems and software cost estimation; resource requirement analysis; the cost of new technologies; and cost analysis of major system modifications. Presently, Professor Bill Gates are the most active in this area.

Manpower Systems Analysis. The focus of research in the Manpower Systems Analysis (MSA) group is on *human* resources. Defense manpower policy makers have been faced with many challenges since the end of the Cold War. Key among these challenges were a reduction of the active-duty force by over 30 percent, budget reductions in recruiting and advertising, a steady operational tempo and deployment schedule with fewer people, new missions, declining levels of public and congressional support for the military, increasing pressure to change the "culture" of military service, renewed efforts toward population representation of women and racial/ethnic minorities throughout the force, a seemingly immovable, high rate of first-term attrition among new recruits, declining levels of personnel

retention in certain critical areas, a number of high-profile "scandals," and others. As the active-duty force was reduced and missions changed, it soon became clear that a smaller military had to be even more skilled and adaptable than the one that witnessed the end of compulsory service and performed so successfully throughout the early 1980s and early 1990s. These challenges confronting defense manpower policy makers are recognized by the MSA group as opportunities for research that will have a lasting impact on the future of the force. MSA research areas can be summarized as follows:

- manpower supply and force requirements;
- improvements in selection and classification of enlisted personnel;
- innovations in recruiting and the application of new technologies;
- improvements in selection of officers and pre-commissioning programs;
- effectiveness of equal opportunity and diversity management programs;
- training effectiveness and efficiency;
- personnel retention in critical fields;
- reduction of first-term attrition rates among enlisted personnel;
- force management and planning, including Reserve components;
- force structure and cost analysis;
- career-force modeling;
- officer promotion and performance; and
- civil-military relations and the All-Volunteer Force;

Professors Mark Eitelberg, Stephen Mehay, and George Thomas are involved in this area.

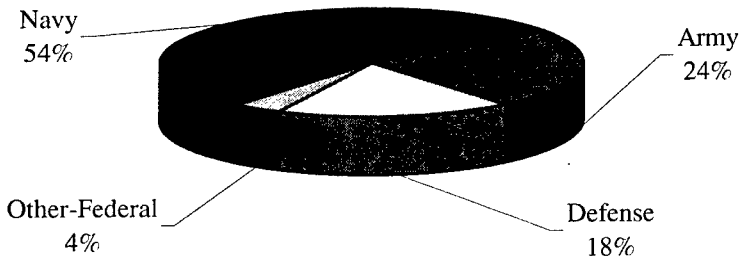
Organization, Systems and Management. Faculty in this functional area pursue basic and applied research on key management issues at a variety of organizational levels. Individual faculty members are acknowledged experts who publish leading-edge research on a variety of issues. Top management issues include strategic planning, change management, stakeholder analysis, organizational design and the development of culture. Human resource management issues include the design of strategic reward systems, managing gender and diversity issues, managing stress, forming career identities, and alternative strategies to training and education (including distance learning). There is a strong expertise in leadership issues, change management, intrinsic motivation, motivational strategies, empowerment, coaching, communications strategies, conflict management, and constructive uses of power.

RESEARCH CENTERS:

The Graduate School of Business and Public Policy is the "home" of the Center for Recruiting Innovation.

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded $49 million in FY2001. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Graduate School of Business and Public Policy is provided below.



Size of Program: **$3823K**

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AGING AIRCRAFT PROJECT

Donald R. Eaton, Senior Lecturer
Graduate School of Business and Public Policy
Sponsor: Naval Air Warfare Center - Aircraft Division

OBJECTIVE: The purpose of the research was to fund student and faculty travel to investigate the issues and concerns of aging aircraft and tactics for remediation and amelioration and thesis support.

SUMMARY: Research on the Aging Aircraft Project focused on acquisition processes, maintenance programs, aircraft wire systems and airframes. Aging risk management, cultural and institutional opportunities and threats to ameliorating the aging phenomena were explored. Pro-active maintenance practices to anticipate aging failures in such a way as to find latent failures before such failures could become catastrophic in terms of safety and cost were also explored. In the case of aging aircraft wire, we recommended a pro-active wire maintenance program that would prevent serious wire failures and tied such a maintenance program to Reliability Centered Maintenance (RCM) concepts.

THESES DIRECTED:

Bailey, C. and Kuenzli, J., "Making Systems Supportability a Reality," Masters Thesis, Naval Postgraduate School, December 2001.

Brown, K., Edge, W., Raia, G. and Ray, J., "Crossbow: a Logistics Maintenance Concept," Masters Thesis, Naval Postgraduate School, December 2001.

Fowler, M., "Acquisition Strategies for Aging Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

Tambouratzis, V., "Aging Aircraft Wiring: a Proactive Maintenance Methodology," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Air Vehicles, Materials, Processes, and Structures

KEYWORDS: Aging Aircraft, Aircraft Maintenance, Latent Failure

DEVELOPMENT OF AN INTERNET-BASED ONLINE RECRUITING STATION (ORS)

Mark J. Eitelberg, Professor
Graduate School of Business and Public Policy
Sponsor: Office of the Deputy Assistant Secretary of Defense (Military Personnel Policy) and Commander, Navy Recruiting Command

OBJECTIVE: To develop a comprehensive Web site that provides an interactive, multimedia-rich, online community environment for learning about, exploring, and applying for Navy jobs.

SUMMARY: Previous research suggests that military recruiting efforts can be improved through greater use of the Internet. In 1999, the Naval Postgraduate School (NPS) experimented with a "mock-up" of a new approach to recruiting called the Online Recruiting Station (ORS). The results of these and other experiments have been quite promising. The initial development of ORS focused on three main components: 1) a Self-Discovery module that would help potential recruits identify their career interests and work values, and assess other pertinent work-related information as well as the likelihood of being considered for a Navy job; 2) an E-Business module (enlistment forms and pre-qualification assessment, in interactive form); and 3) an Online Community environment, including a chat room, instant messaging, and other features. All components would be presented in a multimedia format, with state-of-the-art technology. An online game would serve as the central feature of ORS. The game would have elements that allow for assessment of player (or potential applicant) skills; and characters within the game would advance through scenarios by participating in the three components of Self-Discovery, E-

Business (pre-enlistment forms), and Community or team tasks. Additionally, other potential attractions would be offered through the site: viewing selected events (e.g., flight operations on an aircraft carrier; "battle stations" at boot camp; etc.); and selected commands would staff the chat rooms during specified periods of time (allowing young visitors to "talk" with sailors about their jobs).

This marked the second year of the multi-year project. Under the original plan, ORS would be developed as an advanced, proof-of-concept prototype. A pilot or "beta" system would follow. A production system would be developed and subsequently launched upon completion of testing and evaluation of the ORS pilot. The project was suspended in 2001, despite strong support within the Office of the Secretary of Defense and Department of the Navy, when required funding was discontinued.

THESIS DIRECTED:

Wilcox, A.G., "Recruiting the Next Generation: A Study of Attitudes, Values, and Beliefs," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Recruiting, Enlistment Screening, Internet Applications, Military Manpower

STUDIES OF NAVY RECRUITING WEB SITE

Mark J. Eitelberg, Professor
Graduate School of Business and Public Policy
Sponsor: Commander, Navy Recruiting Command

OBJECTIVE: To provide research support to the Commander, Navy Recruiting Command, leading to the development of "Life Accelerator," the principal component and organizing theme of the new recruiting Web site, "Navy.com."

SUMMARY: This project pulled together information from a variety of previous studies relating to the general effectiveness of Navy recruiting through the Internet. Major topics included the following: background information on the target population of military-age youth; perceptions of the military by the so-called "Net Generation"; the expectations and views of recruiting "influencers," such as teachers, guidance counselors, parents, and older siblings; the comparative attractiveness for recruiting of various Internet features; Internet applications to evaluate the interests, personality types, and vocational aptitudes of potential recruits; the effective elements of a youth-oriented "virtual community"; the comparative effectiveness of presenting Navy opportunities in a variety of formats; the use of realistic job previews in presenting Web-based information on the Navy; and other areas related to improving the effectiveness of the Navy's new recruiting Web site.

THESIS DIRECTED:

Wilcox, A.G., "Recruiting the Next Generation: A Study of Attitudes, Values, and Beliefs," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Recruiting, Recruiter Performance, Personnel Attrition, Training Attrition, Training Performance, Manpower, Personnel, and Training (MPT) Databases

ONLINE RECRUITING STATION

Mark J. Eitelberg, Professor
Graduate School of Business and Public Policy
Sponsor: Directorate for Accession Policy, Office of the Secretary of Defense

OBJECTIVE: To clarify the Online Recruiting Station (ORS) vision, outline the project plan, build partnerships, define organizational roles and responsibilities, specify preliminary requirements and resources, gain agreement among stakeholders on immediate and long-term funding, and identify contractors to assist with separate portions of ORS development.

SUMMARY: This is a relatively small project that extends research for a much larger, multi-year effort. The results of the study are intended to expand existing knowledge and information that would ultimately lead to the design, development, construction, application, testing, and continued evaluation and improvement of ORS. The ORS vision and general project plan were outlined in a document, "The Online Recruiting Station: Vision, Planning, and Preliminary Requirements" (restricted distribution). Additionally, a detailed project plan was developed, specifying milestones, costs, personnel requirements, and organizational responsibilities. Agreements were reached on inter-agency partnerships and responsibilities, including the details of immediate and long-term funding. Potential contractors were identified, interviewed, and assessed for their potential contributions, roles, and comparative costs.

PUBLICATION:

Eitelberg, M.J., "Women and Minorities in the Military: Charting a Course for Research," *Managing Diversity in the Military*, Dansby, M.R., Stewart, J.B. and Webb, S.C., (eds.), New Brunswick, NJ, Transaction Publishers, 2001.

PRESENTATION:

Eitelberg, M.J., "America's All-Volunteer Force: Who Serves and Why Should We Care?," Invited Paper, Notestein Seminar Series, Office of Population Research, Woodrow Wilson School of Public and International Policy, Princeton University, December 2001.

THESIS DIRECTED:

DiEugenio, D.G., "Business Process Redesign in Marine Corps Recruiting with Visual Modeling and Simulation," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Recruiting; Enlistment Screening; Internet Applications; Military Manpower

SUPPORT TO THE EXECUTIVE STEERING GROUP FOR COMMERCIAL BUSINESS PRACTICES PILOT

Kenneth J. Euske, Professor
Graduate School of Business and Public Policy
Sponsor: Naval Air Systems Command

OBJECTIVE: The objective of this proposal is to provide support to the executive steering group for commercial business practices practice. After each executive steering group meeting a report will be provided to the executive steering group. The report is normally in an electronic format.

SUMMARY: The PI attended the monthly meeting of the Executive Steering Group and provided feedback and recommendations to the sponsor.

DoD KEY TECHNOLOGY AREAS: Other (Business Management)

KEYWORDS: Commercial Business Practices, Pilot, ERP

INTELLIGENT AGENTS AND WEB-BASED MARKETS FOR DETAILING NAVAL PERSONNEL

William R. Gates, Associate Professor
Mark E. Nissen, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Naval Personnel Research Studies & Technology and Naval Postgraduate School

OBJECTIVE: Analyze the technological and operational feasibility of establishing a web-based market, using intelligent agents, to match naval enlisted personnel to specific navy billets.

SUMMARY: This multi-year research analyzes the technological and operational feasibility of establishing a web-based market, using intelligent agents, to match naval enlisted personnel to specific navy billets. This system will be part of a general DoN Sailor Career Management System that manages cradle to grave career paths to facilitate both recruiting and retention by enhancing the quality of life within DoN.

Research in 2001 involved three general research areas: developing the relevant information technology and software, identifying the appropriate assignment algorithm and integrating the web-based system into DON's current detailing process. Work modified an extant prototype "intelligent mall" intended for a commercial product setting to reflect a Navy personnel metaphor. A more-robust prototype agent/market system, renamed the "Personnel Mall," was constructed. This, more-robust prototype demonstrates the ability for this technology to meet the requirements envisioned in this application. This integrated agent/market was tested using representative sailors and jobs in a "laboratory setting," to examine actual versus predicted matching performance for both human detailers and the two-sided matching algorithm. Economics experiments were used to test quality of fit in assignments made by both human detailers and the two-sided matching algorithm. A simulation model was developed to test the two-sided matching algorithm's ability to conform to Navy policy (e.g., fill high priority billets, assign all sailors to jobs, etc.).

PUBLICATIONS:

Gates, W.R. and Nissen, M.E., "Designing Agent-Based Electronic Employment Markets," *Electronic Commerce Research Journal*, Vol. 1, No. 3, Special Issue on Theory and Application of Electronic Market Design, pp. 239-263, 2001.

Gates, W.R. and Nissen, M.E., "Experimental Analysis of e-Employment Market Design," *Journal of Organizational Computing And Electronic Commerce*, forthcoming 2002.

Gates, W.R. and Nissen, M.E., "Agent- and Web-based Employment Marketspaces in the U.S. Department of Defense," *A. Gronlund* (ed.), Electronic Government: Design, Applications and Management, Hershey, PA, Idea Group Publishing, 2002.

Nissen, M.E., Gates, W.R., et al., "Web-Based Market for Improving Naval Personnel Detailing," *Naval Postgraduate School Research*, Vol. 11, No. 2, Naval Postgraduate School, June 2001.

Gates, W.R. and Nissen, M.E., "An Empirical Investigation of e-Employment Market Designs," in *Proceedings: The Fourth International Conference on Electronic Commerce Research (ICECR-4)*, Dallas, TX, pp. 93-115, 8–11 November 2001.

PRESENTATIONS:

Gates, W.R. and Nissen, M.E., "The Navy Enlisted Detailing Process: An Empirical Analysis," Western

Economics Association International Meetings, Seattle, WA, 29 June–3 July 2002.

Butler, V., Molina, V., Nissen, M. and Gates, W., "Characterizing Sailor and Command Enlisted Assignment Preferences," Navy Manpower Research and Analysis Conference, Center for Naval Analysis, Alexandria, VA, 14-15 February 2002.

Koh, G., Nissen, M. and Gates, W., "A Redesign of the U.S. Navy's Enlisted Assignment Process," Navy Manpower Research and Analysis Conference, Center for Naval Analysis, Alexandria, VA, 14-15 February 2002.

Gates, W. and Nissen, M., "Designing Agent-Based Electronic Employment Markets," Western Economics Association International Meetings, San Francisco, CA, 7 July 2001.

Gates, W. and Nissen, M., "Intelligent Agents and Web-Based Markets for Detailing Naval Personnel," Military Personnel Research Science Workshop, Fogelman Executive Conference Center, University of Memphis, TN, 4 June 2001.

THESES DIRECTED:

Hill, K., "Comparative Assessment of Air Force Enlisted Detailing Process," Masters Thesis, Naval Postgraduate School, March 2001.

Ng, H.S. and Soh, C.G., "Designing an Agent-based Simulation System to Demonstrate the Advantages of an Electronic Employment Market in a Large Military Organization," Masters Thesis, Naval Postgraduate School, March 2001.

Robards, P., "Matching Algorithms for an Intelligent Mall-Based Detailing Process," Masters Thesis, Naval Postgraduate School, March 2001.

Tan, S.J. and Yeong, C.M., "Economics Experiments to Demonstrate an Electronic Employment Market in a Large Military Organization," Masters Thesis, Naval Postgraduate School, March 2001.

Wasmund, T.R., "Analysis Of The U.S. Army Assignment Process: Improving Effectiveness and Efficiency," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Computing and Software, Modeling and Simulation

KEYWORDS: Intelligent Agents, Web-Based Markets, Two-Sided Matching Games

NAVY AIRLIFT

William R. Gates, Associate Professor
Graduate School of Business and Public Policy
Alan Washburn, Professor
Department of Operations Research
Sponsor: Chief of Naval Operations (N78)

OBJECTIVE: The Navy operates a fleet of operational support aircraft (OSA) that have the function of moving high priority passengers and cargo in wartime. The fleet is aging, and must gradually be replaced with more modern aircraft. The objective is first to measure the wartime demand for OSA transport in the event of a major war, and then to design a fleet that satisfies that demand at minimal cost.

SUMMARY: The basic approach is to estimate wartime demand for OSA transport, and then design a fleet that can meet that demand efficiently, bearing in mind that the costs of current OSA aircraft are "sunk." A fleet management tool OSAMIX is developed as an Excel workbook. Peacetime demand is

estimated by recovering appropriate records from the JALIS database system, and then inflated to prospective wartime demand by applying a "surge factor." Given the characteristics of various aircraft, OSAMIX then finds the fleet that minimizes the present value of the costs of meeting that demand. One conclusion is that it is cost-effective for the Navy to retire its fleet of C-12 turboprop aircraft in favor of a similarly scaled jet aircraft.

PUBLICATIONS:

Gates, W. and Washburn, A. "The Navy Operational Support Aircraft Fleet," Naval Postgraduate School Progress Report, OR-01-006-PR, 2001.

THESES DIRECTED:

Law, J., "Assessing the Performance and Cost of Logistics Airfleet Options," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREA: Other (Military Airlift)

KEYWORDS: OSA, Aircraft Scheduling, Cost Effective

SEA BASED WAREHOUSING

Kevin R. Gue, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Office of Naval Research

OBJECTIVE: To develop throughput and storage system models for cross-docks and transshipment points, with particular application to sea base design in Sea Based Logistics.

SUMMARY: Throughput models for unit-load cross docking systems were developed, including a new type of queue called a staging queue. Analytical results were obtained with a continuous-time Markov chain model of the system, and built simulation models for more complex systems. Uses of the model in stream off-load operations and for the future sea based warehouse platform were proposed.

PUBLICATIONS:

Bartholdi, J., III, Gue, K. and Kang, K., "Staging Freight in a Crossdock," *Proceedings of the International Conference of Industrial Engineering and Production Management*, Quebec City, Canada, May 2001.

Gue, K. and Kang, K.. "Staging Queues in Material Handling and Transportation Systems," *Proceedings of the 2001 Winter Simulation Conference*, Washington DC, December 2001.

DoD KEY TECHNOLOGY AREA: Other (Logistics and Transportation)

KEYWORDS: Distribution, Logistics, Warehousing, Crossdocking, Simulation.

ANALYSIS OF BUDGET REDUCTION, COST-AVOIDANCE AND FINANCIAL MANAGEMENT INITIATIVES IN COMNAVAIRPAC

Lawrence R. Jones, Professor
Jerry L. McCaffery, Professor
Graduate School of Business and Public Policy
Sponsors: Office of the Comptroller, COMNAVAIRPAC and Naval Postgraduate School

OBJECTIVE: To provide assistance to the Office of the Comptroller, AIRPAC in analysis of initiatives for improving command management and management control, cost-reduction and cost avoidance in the Flight Hour Program (FHP) and in accommodating budget reduction.

SUMMARY: The project provided analytical assistance to the Office of the Comptroller, AIRPAC in responding to the necessity for reviewing and assessing options for improving command management and management control, achieving cost-reduction and avoidance in the Flight Hour Program (FHP) and accommodating budget reduction in the period FY 2000 and beyond.

PUBLICATIONS:

Jones, L.L, McCaffery, J.L., Thompson, F. and Zumeta, W., "Public Management for the New Millennium: Developing Relevant and Integrated Professional Curricula," *The International Public Management Review*, 2 February 2001.

Jones, L.L. and McCaffery, J.L., "Public Management Reform – A Symposium," *International Public Management Review*, 2 January 2001.

Jones, L.L. and McCaffery, J.L., "Symposium on Public Management Reform and E-Government," *International Public Management Journal*, 4 February 2001.

Jones, L.L., McCaffery, J.L and Thompson, F., "Performance Budgeting and Accounting in the Public Sector," in A. Kahn, ed., *Budget Theory*, New York, State University of New York Press, 2001.

Jones, L.R., et. al. "Developing Integrated Public Management Curricula," International Public Management Network Workshop, Odense, Denmark, July 2001.

McCaffery, J.L., and Jones, L.R., *Budgeting and Financial Management in the Federal Government*, Greenwich, CT, Information Age Press, 2001.

THESES DIRECTED:

Kimmel, C. and Butzirus, E., "Alternative Command Funding and Functional Organization at the SPAWAR Command," Masters Thesis, Naval Postgraduate School, June 2001.

Phillips, E.A., "An Investigation of Flight Hour Cash Management at CNAP," Masters Thesis, Naval Postgraduate School, June 2001.

Sims, T. and Angela M., "Assessing the Outcomes of Regionalization in Navy Region Southwest," Masters Thesis, Naval Postgraduate School, June 2001.

Kask, A., "Program Budgeting to Improve Decision Making and Resource Planning in Estonian Defense," Masters Thesis, Naval Postgraduate School, June 2001.

Sabel, M., "Naval Special Warfare Command Implementation of the CFO Act," Masters Thesis, Naval Postgraduate School, September 2001.

Duma, D., "A Cost Estimation Model for CNAP Tacair Aviation Depot Level Repair Costs," Masters Thesis, Naval Postgraduate School, December 2001.

Ma, W., "Cost Analysis of the USMC Federal Employees Compensation Act Program," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Other (Resource Management)

KEYWORDS: Resource Management, Financial Management, Management Reform

MODELING AND SIMULATION OF SEA-BASED COMBAT LOGISTICS UTILIZING AN LHD AMPHIBIOUS ATTACK SHIP

Keebom Kang, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Facilities and Engineering Service Center

OBJECTIVE: The objective of this project is to investigate ways to improve the ability to re-supply/replenish combat materiel utilizing LHD amphibious attack ships. It addresses the requirements in terms of sea-based logistics, inter-ship/intra-ship movement, stowage issues, material handling issues, total asset visibility issues, and recommendations for consideration in future ship designs.

SUMMARY: This study analyzes the concept of Sea Based Logistics in the area of inter-ship and intra-ship movement of materiel as well as ship-to-objective materiel movement. Two simulation models have been developed to evaluate the capability of current LHD-class amphibious ships to sustain a force deployed ashore. Results indicate a substantial increase in the number of aircraft, operational availability of those aircraft, and/or a substantial reduction in sustainment requirements are needed in order to successfully accomplish the stated scenarios of this study. The results of this study could support the design of future LHD-class ships.

PRESENTATIONS:

Kang, K., Brief to the Modeling and Simulation Group at the Naval Facilities and Engineering Service Center (NFESC), Port Hueneme, CA, August 2001.

Kang, K., Brief to supply officers onboard *USS Bonhomme Richard* (LPD 6), August 2001.

THESES DIRECTED:

Curtin, M., "Analysis of Inter/Intra Ship Material Movement in Sea Based Logistics Using Simulation," Masters Thesis, Naval Postgraduate School, June 2001.

Bryan, K., "Simulation of Sea Base Logistics Support of Operational Maneuver from the Sea," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Readiness, Sealift, Sea-Based Logistics, Simulation and Modeling

EVALUATION OF EFFICIENT OFFICER COMMISSIONING SOURCE MIXES

Janice H. Laurence, Research Associate Professor
Graduate School of Business and Public Policy
Sponsor: Office of the Secretary of Defense

OBJECTIVE: The object of this proposal is to assess alternative officer commissioning sources and source mixes.

SUMMARY: The Principal Investigator provides on-site consultation and analysis of officer

commissioning source and mix policy issues.

DoD KEY TECHNOLOGIES AREAS: Manpower, Personnel and Training

KEYWORDS: Officer Commissioning Source, Academy, ROTC, OCS

STUDY AND ANALYSIS OF INSIDER THREAT

Janice H. Laurence, Research Associate Professor
Graduate School of Business and Public Policy
Sponsor: Central Intelligence Agency

OBJECTIVE: To provide a documented description of the background, characteristics, and behaviors of insiders who pose threats to national security and the safekeeping of classified information. Included are threats from information technology. In addition to the characteristics of individuals, environmental aspects will also be uncovered along with potential interactions between individual and environmental factors. From these data, insider threat models will be developed along with recommendations for policies and procedures that will ameliorate the vulnerabilities.

SUMMARY: Analysis of a database on security violations housed by the National Reconnaissance Office (NRO) was conducted. Based on the results, a follow-on study and protocol were developed for administration to cleared personnel who have committed cyber security violations. A related study was designed (including protocol and proposal submitted to the FBI Institutional Review Board) for assessing cyber crimes among non-cleared personnel who are incarcerated. A synopsis of the Intelligence Community's SLAMMER project was prepared and a research prospectus was forwarded to the FBI so as to gain access to the SLAMMER data. SLAMMER is a classified project that consists of transcriptions of interviews with convicted spies against the United States. These data show potential for secondary analysis from a counterintelligence perspective. Further, the data show potential for designing training scenarios for personnel security purposes.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Personnel Security, Insider Threat, Background Investigations, Security Vulnerability

EXTERNAL ACQUISITION RESEARCH PROGRAM

Ira Lewis, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Defense Acquisition University

OBJECTIVE: The mission of the External Acquisition Research Program (EARP) is to significantly increase the quality and quantity of acquisition research. It aims to expand the base of researchers interested in topics germane to Department of Defense (DoD) acquisition and to produce new and relevant knowledge and solutions from a variety of disciplines. The program targets researchers at leading universities outside of DoD's customary sphere of influence and support, but is open to scholars at all institutions capable of top quality acquisition research.

SUMMARY: Work as Program Manager has included: 1) Leading the evaluation team for FY2001 research proposals received from academic institutions; 2) Responsibility for a budget of $300,000 (FY2002); 3) Marketing the program to academic institutions and DOD agencies; and 4) Contract management.

DoD KEY TECHNOLOGY AREA: Other (Acquisition and Contracting)

KEYWORDS: Acquisition, Contracting

ANALYSIS OF NAVY RECRUITS' BACKGROUND FACTORS AND ATTITUDES

Stephen L. Mehay, Professor
Graduate School of Business and Public Policy
Sponsor: Naval Education and Training Professional Development and Technology Center

OBJECTIVE: The Navy has been experiencing high attrition rates during basic training for high school graduates. Information is needed on recruits' background characteristics and attitudes that could be used to facilitate their transition to military life.

SUMMARY: The purpose of this effort is to automate and analyze responses from about 10,000 bio-questionnaires administered to high school graduate recruits and to identify factors associated with their behavior during later basic training. If successful, the Navy could use this information to identify recruits in need of special, early assistance to help them complete basic training.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: Attrition, Recruiting

GENERAL EDUCATIONAL DEVELOPMENT (GED) SCREENING PILOT STUDY -- PART II

Stephen L. Mehay, Professor
Graduate School of Business and Public Policy
Sponsor: Chief of Naval Operations (N1H)

OBJECTIVE: The purpose of this study is to identify and evaluate procedures for the increased recruitment and improved selection of GED certificate holders to meet Navy procurement goals. If successful, the Navy could broaden its recruitment base and reduce first-term attrition.

SUMMARY: The effort will develop and pre-test a biographical questionnaire and evaluate its productivity in obtaining relevant behavioral information. The study will prepare guidelines for the administration of the questionnaire at the MEPS and prepare the data for subsequent statistical analysis.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: GED, Recruitment, Selection, Attrition

MODELS OF NAVY COMPENSATION AND RETENTION BEHAVIOR

Stephen L. Mehay, Professor
Graduate School of Business and Public Policy
Sponsor: Navy Personnel Research, Studies and Technology Center

OBJECTIVE: Navy is currently building a personnel data warehouse (PerSMART) that, in part, will be used to support the management of retention and Navy end-strength. The data warehouse will be constructed based on individual records derived from the Navy Enlisted Master File (EMF). When completed, PerSMART will contain a module called the Retention Monitoring Systems (RMS) that will allow analysts to calculate reenlistment and extension rates for individual sailors identified by rating, NEC, zone, and other important characteristics. Navy Personnel Bureau analysts require that the new data warehouse incorporate a Retention Modeling Module (RMM) that will support various types of more sophisticated statistical analysis of retention behavior.

SUMMARY: The purpose of this effort is to provide assistance in identifying and obtaining key elements needed for the Retention Modeling Module. The study will survey the literature military compensation and retention. The survey will provide the guide for the data fields that will be required to populate the RMM. The study will identify the necessary structure of the retention modeling capability for RMM. Various retention modeling approaches will be reviewed as will the data requirements for

each.

PUBLICATIONS:

Mehay, S., "A Survey of Navy Retention and Compensation Models," Technical Report prepared for Navy Personnel Research, Studies and Technology Center, Millington, TN, July 2001.

THESES DIRECTED:

Bellas, J. and McNally, J., "Navy Retention and Compensation Models," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: Retention, ACOL Models, Compensation

STATISTICAL ANALYSIS OF BASIC TRAINING ATTRITION

Stephen L. Mehay, Professor
Graduate School of Business and Public Policy
Sponsor: Navy Recruiting Command

OBJECTIVE: The purpose of this study is to identify and evaluate procedures for the increased recruitment and improved selection of GED certificate holders to meet Navy procurement goals. If successful, the Navy could broaden its recruitment base and reduce first-term attrition.

SUMMARY: The effort will examine and evaluate a number of different statistical approaches and models that can be applied to pre-service biographical data items as predictors of basic training attrition among high risk applicants, and recommend to the Navy the most effective formula for attrition reduction.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: GED, Recruitment, Selection, Attrition

FEDERAL FINANCIAL REPORTING AND ANALYSIS

Douglas Moses, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Unfunded

OBJECTIVE: The objective of this line of research is to describe and critique current Financial Reporting practices of Federal Government entities and develop methodologies for conducting Financial Statement Analysis appropriate for federal agencies.

SUMMARY: Recent years have seen significant changes within the federal government that impact financial reporting. There has been a general shift toward more "business-like" management practices. There have been initiatives, such as the CFO Act and the Federal Accounting Standards Advisory Board, which have resulted in changes in both the requirement for, and the content of, the financial reporting of federal government activities. This research attempts to construct and validate a framework for conducting financial analysis of federal entities relying on the information available in federal financial reports. The research develops financial ratios designed to communicate the financial condition of federal entities and examines their meaning and properties

THESES DIRECTED:

Belchoff, B., "Analysis of Changes in Federal Financial Ratios," Masters Thesis, Naval Postgraduate School, June 2001.

Murphy, M., "Fundamental Dimensions of Financial Condition in the Federal Government," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Other (Financial Accounting/Reporting)

KEYWORDS: Financial Accounting, Federal Financial Reporting, Financial Ratio Analysis

KNOWLEDGE-FLOW THEORY FOR VERY-LARGE ENTERPRISES

Mark Nissen, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Office of Naval Research

OBJECTIVE: The primary objective of this research is to develop scientific knowledge and understanding (i.e., theory) pertaining to the phenomenon of knowledge flow.

SUMMARY: This, three-year project is funded by the Office of Naval Research (ONR) through its Young Investigator (YI) Program. The YI program is highly-competitive, and winning the corresponding grant award brings national recognition to the Naval Postgraduate School. The basic science associated with this project addresses our poor understanding of how knowledge—viewed as distinct from information and data—flows through the enterprise. To improve this understanding, a program of theory building and testing is conducted through a three-pronged technical approach: 1) develop and refine a model of knowledge-flow theory, emphasizing the very-large enterprise (e.g., Navy, Department of Defense); 2) develop a contingency model for matching the most-appropriate process and system designs to enterprise knowledge-flow patterns; 3) assess the performance effects of alternative knowledge system and process designs through simulation (e.g., of naval warfare, personnel processes).

2001 represents the first year of this project. In this first year, most of the spring quarter was spent onboard the *USS Coronado*, flagship of the Navy's Third Fleet, conducting a case study to investigate the phenomenology of knowledge flow through the Joint Task Force operation. This field research included working, eating and even living onboard this naval warship, while in port in San Diego as well as underway at sea for the Joint Task Force Exercise organized for the VINSON Battlegroup. Preliminary results include a grounded understanding of how knowledge flows are distinct from work flows associated with warfighting, along with the identification, classification and visualization of numerous interrelated knowledge flows using a four-dimensional model developed through integration of theory and empirical data.

PUBLICATIONS:

Oxendine, E. and Nissen, M.E., "Knowledge Process and System Design for the Carrier Battlegroup," *Knowledge and Innovation: Journal of the KMCI 1:3*, 2001.

Nissen, M.E., *Facilitating Naval Knowledge Flow*, Naval Postgraduate School Technical Report, NPS-GSBPP-01-004, 2001.

Nissen, M.E., *Toward a Program of Research on Knowledge Flow in the Very-Large Enterprise*, Naval Postgraduate School Technical Report, NPS-GSBPP-01-003, 2001.

Nissen, M.E. and Oxendine, E., "Integrating Knowledge Process and System Design for Naval Battle Groups," *Advanced Topics in Information Resources Management Idea Group Publishing* (forthcoming 2002).

PRESENTATIONS:

Nissen, M.E., "Research Experiences and Opportunities with the Navy Sea-Based Battle Lab," Invited Presentation for the Naval Postgraduate School, School of Business and Public Policy Research Colloquium, Monterey, CA, September 2001.

Nissen, M.E., "Navy Knowledge Flow," invited presentation, Navy Chief Information Office, Knowledge-Centric Organization Project, presentation filmed in Monterey, CA, May 2001.

Nissen, M.E., "Navy Knowledge Flow Exchange," invited presentation, Command Third Fleet seminar, *USS Coronado*, San Diego, CA, May 2001.

Nissen, M.E., "A Brief Look at Knowledge Flow," invited presentation, Naval Postgraduate School Research Recognition Evening, April 2001.

Nissen, M.E., "A Tale of Three Knowledge Systems," invited presentation, Stanford University Center for Integrated Facilities Engineering, March 2001.

THESES DIRECTED:

Korzilius, H., "The Use of Knowledge Based Decision Support Systems in Reengineering Selected Processes in the U.S. Marine Corps," Masters Thesis, Naval Postgraduate School, September 2001.

Navarro, R., "Knowledge Management and System Design at U.S. Coast Guard Command Centers," Masters Thesis, Naval Postgraduate School, June 2001.

Sorenson, A., "The Coast Guard Knowledge Base: Building Online Guard Communities, Teams, and Experts to Facilitate Rapid Creation, Capture and Sharing of Service Related Knowledge," Masters Thesis, Naval Postgraduate School, June 2001.

OTHER:

"Knowledge Flow through a Military Joint Task Force Operation," in review.

"An Extended Model of Knowledge-Flow Dynamics," in review.

"Defense Project Management Knowledge Flow through Lessons Learned," in review; with Keith Snider.

"Experimental Assessment of a Redesign Knowledge System for Decision Support," in review.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Knowledge, Knowledge Flow, Knowledge Management, Knowledge Superiority, Modeling and Simulation.

WEB-BASED LABOR MARKET DESIGN THROUGH INTELLIGENT AGENTS

Mark Nissen, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Navy Personnel Research Studies and Technologies Office

OBJECTIVE: To design Web-based labor markets for matching sailors with jobs via software agents.

SUMMARY: Associate Professor Bill Gates and the principal investigator broke new ground in terms of both two-sided matching algorithms and multi-agent systems, and we effectively integrated these disciplinary works to create effective market-design goals, approaches and proof-of-concept systems.

This effort has since expanded to include experimental-economics and other work through collaboration with researchers from the University of Mississippi, and our market-design approach has been selected for Navy-wide implementation through its Navy/Marine Corps Career Management System.

PUBLICATIONS:

Gates, W.R. and Nissen, M.E., "Designing Agent-based Electronic Employment Markets," *Electronic Commerce Research Journal*, Special Issue on Theory and Application of Electronic Market Design 1:3, 2001.

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Nissen, M.E. and Gates, W.R., "An Empirical Investigation of e-Employment Market Designs," *Proceedings International Conference on Electronic Commerce Research*, Dallas, TX, November 2001.

PRESENTATIONS:

Nissen, M.E. and Gates, W.R., "An Empirical Investigation of e-Employment Market Designs," presented at the International Conference on Electronic Commerce Research, Dallas, TX, November 2001.

Gates, W.R. and Nissen, M.E., "Designing Agent-Based Electronic Employment Markets," presented at the Western Economics Association International Meetings, San Francisco, CA, July 2001.

Gates, W.R. and Nissen, M.E., "Intelligent Agents and Web-Based Markets for Detailing Naval Personnel," presented at the Military Personnel Research Science Workshop, University of Memphis, TN, June 2001.

THESES DIRECTED:

Ng, H.S., "Designing an Agent-based Simulation System to Demonstrate the Advantages of an Electronic Employment Market in a Large Military Organization," Masters Thesis, Naval Postgraduate School, March 2001.

Soh, C.G., "Designing an Agent-based Simulation System to Demonstrate the Advantages of an Electronic Employment Market in a Large Military Organization," Masters Thesis, Naval Postgraduate School, March 2001.

Robards, P., "Analysis of Two-Sided Matching Algorithms for Naval Personnel Processes," Masters Thesis, Naval Postgraduate School, March 2001.

OTHER:

"Experimental Analysis of e-Employment Market Designs," in review, with Bill Gates.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel, and Training

KEYWORDS: Agents, Economics, Information Systems, Labor Markets, Personnel, Process Innovation, Research

FINANCIAL REPORTING AND ANALYSIS RESEARCH FOR THE DEPARTMENT OF DEFENSE PERSONNEL SECURITY RESEARCH CENTER

Joseph G. San Miguel, Professor
Graduate School of Business and Public Policy
Sponsor: Department of Defense Security Research Center

OBJECTIVE: The objective of the research during the third year of this program was to assist the security agencies in applying financial analysis techniques to live data obtained from federal employees in positions of national security. Prior work recommended new tools for uncovering unexplained affluence or financial distress. The results have financial implications for security policies and programs of the Defense Investigative Service, the National Security Agency, the Central Intelligence Agency, and the U.S. Customs.

SUMMARY: Numerous initiatives are underway to evaluate the quality of financial and non-financial information for purposes of deterring or detecting security threats. Prior investigation and research has established that financial incentives and payments are generally the primary motives for acts of spying by U.S. citizens. The well-known spy cases involving Aldrich Ames and John Walker are examples. This project considers the use the financial information for use as predictors of potential security risks and the need for security investigations. Financial information includes unexplained increases or decreases in an individual's net worth. The various sources of net worth such as earned income, inheritance, or sale of personal assets as well as the uses of net worth for investments and asset acquisitions, are variables that must be considered. Due to the sensitivity of the subject, the reports prepared for the sponsor and the other federal agencies are CLASSIFIED.

PUBLICATIONS:

San Miguel, J.G., "Application of Financial Ratios to Vertical and Horizontal Analysis of the National Security Agency's Financial Disclosures," Classified Report, Department of Defense, Security Research Center, 15 September 2001.

THESIS DIRECTED:

Lee, L., "Financial Analysis of Federal Employee Financial Disclosures to Identify Unexplained Affluence and Financial Stress," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Other (National Security)

KEYWORDS: National Security, Financial Analysis, Cost Analysis, Cost Estimation

THE STRATEGIC IMPACT OF ENTERPRISE RESOURCE PLANNING SYSTEMS

Joseph G. San Miguel, Professor
Graduate School of Business and Public Policy
Sponsor: Financial Executive Research Foundation

OBJECTIVE: In recent years, business enterprises have made significant investments in information technology called enterprise resource planning systems to improve their strategic positioning, responsiveness to the customer, and market direction. This research examines a number of companies that have implemented enterprise resource planning systems to better understand the roles and responsibilities of financial managers and the resulting strategic information and performance measurement systems.

SUMMARY: For survival and growth in the global marketplace a firm must effectively allocate its strategic resources, which include human, physical, and financial assets, across business operations and processes. Its strategy must be supported by management systems that assist the planning and control of

operations and processes. Today information technology supports these information systems. In recent years enterprise resource planning (ERP) systems have been used as a means to comprehensively link firm–wide operations and processes. The majority of the thousand largest firms in the U.S. have either implemented or in the process of implementing enterprise resource planning systems. Because of the millions of investment dollars involved, executive management is keenly aware of ERP and its promised benefits. Today, ERP vendors and IT consultants are also targeting middle–level firms with annual sales less than $1 billion. The question is how effective are these significant investments in assisting executive management in achieving corporate objectives.

PUBLICATIONS:

San Miguel, J.G., "Dallas Consulting Group," in Blocher, E.J., et al., *Cases and Readings in Cost Management*, Irwin/McGraw-Hill, 2002.

San Miguel, J.G., "Emerson Electric Company," in Blocher, E.J., et al., *Cases and Readings in Cost Management*, Irwin/McGraw-Hill, 2002.

San Miguel, J.G. and Shank, J.K., "ERP as a Strategic Management Tool: Six Evolutionary Stages," *Handbook of Cost Management*, Warren, Gorham, Lamont, 2001.

THESES DIRECTED:

Banasiewicz, R., "Developing a Model to Assess Information Technology Investment Management in Government Agencies," Masters Thesis, Naval Postgraduate School, June 2001.

Leighty, J.E., "Criteria for Evaluating United States Marine Corps Installation Strategic Management," Masters Thesis, Naval Postgraduate School, December 2001.

Schweighardt, E., "Electronic Chart Display and Information System—Navy Analysis and Recommendations," Masters Thesis, Naval Postgraduate School, June 2001.

Shearon, B.T., "The Cost Effectiveness of West Coast Distributed Simulation Training for Pacific Fleet," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Other (Cost Management)

KEYWORDS: Financial Analysis, Cost Analysis, Cost Estimation, Strategy

ACQUISITION CENTER FOR RESEARCH AND LESSONS LEARNED (ACQUISITION CENTRAL)

Keith F. Snider, Associate Professor
Graduate School of Business and Public Policy
Sponsor: TRADOC Analysis Command

OBJECTIVE: The objective of this proposal is to develop, implement and operate a virtual center to focus research resources on relevant and important acquisition issues, provide a means to make research results accessible to the acquisition community, serve as an integrating mechanism for acquisition research needs of warfighters, policy-makers and practioners.

SUMMARY: A virtual center has been established, tested, and put on line for access by policy-makers and practitioners.

DoD KEY TECHNOLOGY AREAS: Other (Systems Acquisition)

KEYWORDS: Acquisition, Acquisition Research, Lessons Learned

GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

2001
Faculty Publications and Presentations

JOURNAL PAPERS

Boudreau, M., "Transitioning From Fielding to Steady-State Sustainment," *Army AL&T*, pp. 31-32, January-February 2001.

Fowler, D.N. and Nissen, M.E., "Innovating the Federal Acquisition Process through Intelligent Agents," *Acquisition Review Quarterly* 8:3, 2001.

Gates, W.R. and Nissen, M.E., "Designing Agent-Based Electronic Employment Markets," *Electronic Commerce Research* Journal, Vol. 1, No. 3, Special Issue on Theory and Application of Electronic Market Design, pp. 239-263, 2001.

Gergen, K.J., McNamee, S. and Barrett, F., "Toward Transformative Dialogue," *International Journal of Public Administration*, 24(7&8), pp. 678-707, 2001.

Jones, L.R., "Public Management Reform – A Symposium.," *The International Public Management Review*, Vol. 2, Issue 1, pp. 1-52, 2001.

Jones, L.R., "Symposium on Public Management Reform and E-Government," *International Public Management Journal*, Vol. 4, Issue 2, 2001.

Jones, L.R., Thompson, F. and Zumeta, W., "Public Management for the New Millennium: Developing Relevant and Integrated Professional Curricula," *The International Public Management Review*, Vol. 2, Issue 2, pp. 19-38, 2001.

Jones, L.R. and Thompson, F., "Responsibility Budgeting and Accounting," *International Public Management Journal*, Vol. 3, pp. 205-227, 2001.

Laurence, J.H. "Our Armed Forces Respond to Terror at Home," *Psychological Science Agenda*, Vol. 14, No. 6., pp. 6-7, 2001.

Lewis, I., "Logistics and Electronic Commerce: An Interorganizational Systems Perspective," *Transportation Journal*, 40(4), pp. 5-13, Summer 2001.

Malina, M.A. and Selto, F.H., "Communicating and Controlling Strategy: An Empirical Study of the Effectiveness of the Balanced Scorecard," *Journal of Management Accounting Research*, Vol., 13, pp. 47-90, 2001.

Nissen, M.E., "Measurement-driven Enterprise Systems Engineering," *Journal of Engineering Valuation and Cost Analysis* 4:1, 2001.

Nissen, M.E., "Beyond Electronic Disintermediation through Multi-Agent Systems," *Journal of Logistics Information Management* 14:4, 2001.

Nissen, M.E., "Agent-Based Supply Chain Integration," *Journal of Information Technology and Management* 2:3, Special Issue on Electronic Commerce in Procurement and the Supply Chain, 2001.

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Snider, K. F. and Walker, M. F., "Best Practices and Protests: Toward Effective Use of Past Performance As a Criterion in Source Selections," *Journal of Public Procurement*, Vol. 1, Issue 1, pp. 96-122.

Suchan, J., "The Effect of Interpretive Schemes on Videoteleducation's Conception, Implemention, and Use," *Journal of Business and Technical Communication*, Vol. 15, No. 2, pp. 133-163, April 2001.

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Henderson, D.R., *The Joy of Freedom: An Economist's Odyssey*, Financial Times Prentice Hall, 2001.

McCaffery, J.L. and Jones, L.R, *Budgeting and Financial Management in the Federal Government*, Greenwich, CT, Information Age Press, 2001.

Thomas, K., *Motivacion y Plenitud 8 Horas al Dia*, Mexico City: Mondadori, 2001. (Motivation and Fulfillment Eight Hours a Day, Spanish translation of K. Thomas, *Intrinsic Motivation at Work*, San Francisco, Berrett-Koehler, 2000.)

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Eitelberg, M.J., "Women and Minorities in the Military: Charting a Course for Research," in *Managing Diversity in the Military*, Dansby, M.R., Stewart, J.B. and Webb, S.C., (eds.), New Brunswick, NJ, Transaction Publishers, 2001.

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Bartholdi, J.J., III, Gue, K.R. and Kang, K., "Staging Freight in a Crossdock," *Proceedings of the International Conference of Industrial Engineering and Production Management*, Quebec City, Canada, May 2001.

Gates, W.R. and Nissen, M.E., "An Empirical Investigation of e-Employment Market Designs," *Proceedings: The Fourth International Conference on Electronic Commerce Research (ICECR-4)*, pp. 93-115, Dallas, TX, 8–11 November 2001.

Gue, K.R. and Keebom, K., "Staging Queues in Material Handling and Transportation Systems," *Proceedings of the 2001 Winter Simulation Conference*, Washington, DC, December 2001.

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Hutchins, S.G., Kemple, W.G., Poirier, J.A. and Hocevar, S.P, "Use of a Novel Organizational Structure to Support Complex Decisionmaking During Global Wargame 2001," *Proceedings of the 6th International Command and Control Research and Technology Symposium*, U.S. Naval Academy, Annapolis, MD, 2001.

Hutchins, S.G., Kemple, W.G., Poirier, J.A., Hocevar, S.P., Kleinman, D.L. and Sovereign, M.G., "Use of Information Technology to Develop a Collaborative Decision Support System for Command and Control,"

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CONFERENCE PRESENTATIONS (WITHOUT PUBLICATION)

Doerr, K., "An Empirical Comparison of Two Models of Task Completion Time," 2001 Academy of Management Conference, Washington D.C.

Eitelberg, M.J., "Bridging the Gap Between Defense and Public Administration," Annual Meeting of the American Society for Public Administration, Newark, NJ, March 2001.

Eitelberg, M.J., "America's All-Volunteer Force: Who Serves and Why Should We Care?" Notestein Seminar Series, Office of Population Research, Woodrow Wilson School of Public and International Affairs, Princeton University, December 2001.

Gates, W.R. and Nissen, M.E., "Designing Agent-Based Electronic Employment Markets," Western Economics Association International Meetings, San Francisco, CA, 7 July 2001.

Gates, W.R. and Terasawa, K.L., "Reconsidering Publicness in Alliance Defense Expenditures: NATO Expansion and Burden Sharing," Western Economics Association International Meetings, San Francisco, CA, 7 July 2001.

Gates, W.R. and Nissen, M.E., "Intelligent Agents and Web-Based Markets for Detailing Naval Personnel," Military Personnel Research Science Workshop, Fogelman Executive Conference Center, University of Memphis, TN, 4 June 2001.

Hirsch, B. and Mehay, S., "Evaluating the Labor Market Experiences of Veterans Using a Matched Comparison Group Design," Annual Meetings of the Southern Economic Association, Tampa, FL, November 2001.

Hocevar, S.P., Kemple, W.G. and Hutchins, S.G., "Self-Synchronization: Preliminary Simulation-Based Research on Where it Effectively Occurs and Key Enablers," 69th Annual Military Operations Research Society Symposium (MORSS), U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Hocevar, S.P., Cuskey, J. and Gray, J., "New Directions in Defense Contracting: A Customer Focus," Annual Conference of the American Society for Public Administration, Rutgers University, Newark, NJ, March 2001.

Hutchins, S.G., Poirier, J.A., Kemple, W.G., Hocevar, S.P. and Kleinman, D.L., "Functionality Required for a Collaborative Command and Control Decisionmaking System," 69th Annual Military Operations Research Society Symposium (MORSS), U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Hutchins, S.G., Poirier, J.A., Kemple, W.G. and Hocevar, S.P., "Effectiveness of a Novel C2 Organizational System Used During Global Wargame 2000," Annual Military Operations Research Society Symposium (MORSS), U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Jones, L.R., et. al. "Developing Integrated Public Management Curricula," International Public Management Network Workshop, Odense, Denmark, July 2001.

Lamm, D., "Educating the Acquisition Professional in the 21st Century," University of Minnesota 40th Annual Conference on Government Contracting, Minneapolis, MN, 10-12 October 2001.

Laurence, J.H., "Military Culture and Military Women: Myths and Misunderstanding," 109th Annual Convention of the American Psychological Association, San Francisco, CA, August 2001.

Lewis, I., "External Acquisition Research Program at NPS," American Society of Public Administration Conference, Newark, NJ, 12 March 2001.

Mehay, S. and Webb, N., "Cost-Benefit Analysis of Zero Tolerance Drug Policies," Bi-annual Meetings of the Bay Area Labor Economics (BALE) Association Meetings, Stanford, CA, October 2001.

Mehay, S., "Evaluating the Labor Market Experiences of Veterans Using a Matched Comparison Group Design," RAND/UCLA Labor/Population Seminar, Santa Monica, CA, August 2001.

Mehay, S. and Webb, N., "Program Evaluation of the Navy's Drug Testing Policies," Defense Resource Management Institute's Economics Seminar, Naval Postgraduate School, May 2001.

Nissen, M.E., "BPR Conceptual Modeling," Bureau of Naval Personnel CIO, Millington, TN, December 2001.

Nissen, M.E. and Gates, W.R. "An Empirical Investigation of e-Employment Market Designs," International Conference on Electronic Commerce Research, Dallas, TX, November 2001.

Nissen, M.E., "Navy Knowledge Flow," Navy Chief Information Office, Knowledge-Centric Organization Project, Monterey, CA, May 2001.

Nissen, M.E., "Navy Knowledge Flow Exchange," Command Third Fleet Seminar, *USS Coronado*, San Diego, CA, May 2001.

Snider, K.F., "Studying Defense Acquisition as Public Administration," 62nd National Conference of the American Society for Public Administration, Newark, NJ, 10-13 March 2001.

Snider, K.F., "Integrating Individual And Organizational Learning: The Case Study Approach In Teaching Public Administration And Agency Lessons Learned Systems," 24th Annual Conference on Teaching Public Administration, Tempe, AZ, 4-5 February 2001.

Talalayevsky, A. and Lewis, I., "Automobile Retailing: Will the Internet Support New Channels or Intermediaries," Decision Sciences Institute, San Francisco, CA, 18 November 2001.

Thomas, K. and Tymon, W., "Intrinsic Motivation: Being Energized in Your Work," Analytical Laboratory Managers Association, Keemah, TX, 2 November 2001.

Thomas, K., "Intrinsic Motivation," Colorado Issues Network and Associated Consultants International, Denver, CO, 7 September 2001.

Thomas, K., "Collaborating and the Conflict-Handling Modes," Colorado Issues Network and Associated Consultants International, Denver, CO, 7 September 2001.

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INSTITUTES AND CENTERS

Institute for Information Innovation and Superiority (I2SI)

Institute for Defense Systems Engineering and Analysis (IDSEA)

The Modeling, Virtual Environments, and Simulation (MOVES) Institute

Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS)

INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION (I2SI)

CYNTHIA IRVINE
DIRECTOR

INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION

OVERVIEW:

The Institute for Information Superiority and Innovation was established to be the center for innovative research and education in enabling information technologies, operations, and strategies, with focus on their development and application for national security. The Institute provides a venue for interdisciplinary research in a wide variety of areas related to the capture, processing, display and storage of information in a warfighting environment. Research and educational activities within the Institute are intended to support both immediate and long-term objectives for the effective use of computers and networks within the military.

CURRICULA SERVED:

The Institute for Information Superiority and Innovation does not manage its own curriculum. Instead, students from any curriculum at the Naval Postgraduate School can participate in the Institute's wide range of research and educational programs.

RESEARCH THRUSTS:

- Signals Intelligence
- Electronic Communications Systems
- Electronic Warfare
- Information Warfare
- Information Operations
- Computer and Network Security
- Threat and Risk Analysis and Countermeasures
- System Certification and Accreditation
- Motivations and Operations of Information Threats

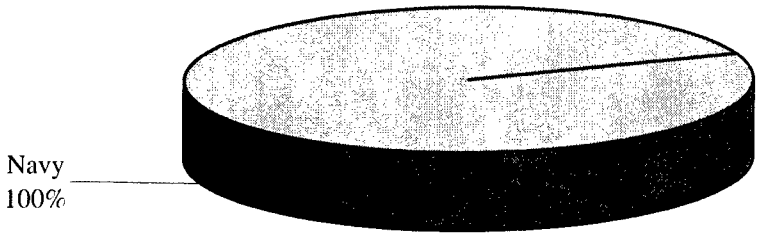
For faculty members investigating these areas, see the research summaries for each faculty member's home department.

RESEARCH CENTERS:

- Cryoptologic Research Center (CRC)
- Center for Information Security (INFOSEC) Studies and Research (CISR)
- Center for the Study of Terrorism and Irregular Warfare

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 Institute for Information Superiority and Innovation (I2SI) is provided below:



Size of Program: $136K

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CDTEMS SUPPORT FOR THE INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION

Cynthia E. Irvine, Associate Professor
Institute for Information Superiority and Innovation and Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: The Institute for Information Superiority and Innovation (IISI) has been formed "to be the center for innovative research and education in enabling information technologies, operations, and strategies, with focus on their development and application for national security." The purpose of this support is to provide initiation funds for I2SI activities.

SUMMARY: The NPS Center for Defense Technology and Education for the Military Services (CDTEMS) provided support for the formation of the Institute for Information Superiority and Innovation (IISI) at the Naval Postgraduate School (NPS) in FY01. The mission of the Institute for Information Superiority and Innovation (IISI) is research, application and education in the challenges facing DoN and DoD in the sciences associated with the collection, protection, dissemination, processing, and display of information.

The FY01 CDTEMS funding was used in support of the institute's creation. In particular, the funding was used to support staff to increase the functionality and visibility of the Institute. Domain names were purchased and a web site was created as well as other doucments. The funding permitted planning for first year projects and supported ongoing efforts to ensure adequate resources for the Institute.

DoD KEY TECHNOLOGY AREA: Computing and Software, Command, Control and Communications, Other (Information Operations, Information Warfare)

KEYWORDS: Information Operations, Information Assurance, Computer Security, Network Security, Information Warfare, Command and Control Systems, Cryptologic Systems

INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION (I2SI)

2001
Faculty Publications
and Presentations

All faculty affiliated with the Institute for Information Innovation and Superiority and Innovation have home departments. See the research summaries for each faculty member's home department for Institute member's presentations and publications.

INSTITUTE FOR DEFENSE SYSTEMS ENGINEERING AND ANALYSIS (IDSEA)

PHIL DEPOY
DIRECTOR

INSTITUTE FOR DEFENSE SYSTEMS ENGINEERING AND ANALYSIS

OVERVIEW:

On May 28, 2002, the Institute for Defense Systems Engineering and Analysis (IDSEA) was officially renamed the Wayne E. Meyer Institute of Systems Engineering (Meyer Institute).

Research facilitated by the Meyer Institute is designed to develop more extensive interactions and participation with Department of Defense (DOD)/Navy/industry teams conducting significant system-based studies and evaluations. Research within the Meyer Institute is conducted by the faculty and through the selection of topics for student theses.

CURRICULA SERVED:

- Computer Science
    - Modeling and Simulation
- Command, Control, Communications and Intelligence (C4I)
- Operational Logistics
- Total Ship Systems Engineering (TSSE)
- Systems Engineering and Analysis (SEA) (formerly known as Systems Engineering and Integration (SEI))
- Aeronautical Engineering
- Oceanography

RESEARCH THRUSTS:

- Scenario Authoring and Visualization
- Mine Warfare
- Anti-Terrorism/Force Protection
- Data Collection and Analysis for Fleet Battle Experiments
- Joint Warfare
- Concept Modeling
- Future Force Structure
- Evolutionary Computing

RESEARCH CHAIRS:

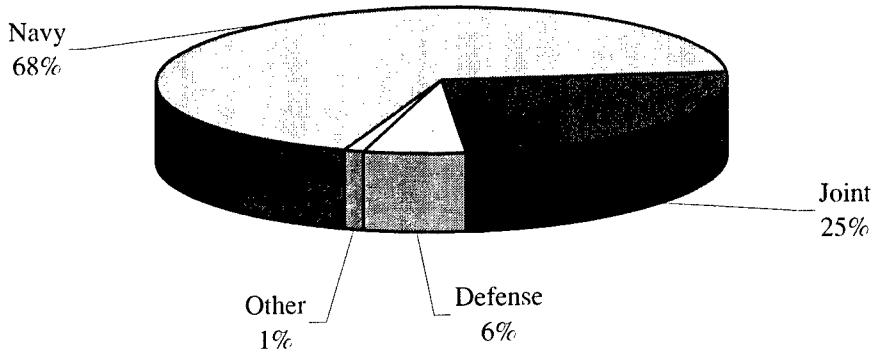
- Expeditionary Warfare

RESEARCH FACILITIES:

- Three Integrated Student Design Labs, consisting of 22 seats, and served by a "War Room" to facilitate team interaction and exchange of ideas.

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 Institute for Defense Systems Engineering and Analysis (IDSEA) is provided below:



Size of Program: $3742K

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MODELING AND SIMULATION TECHNICAL SUPPORT

Curtis L. Blais, Research Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: The Naval Postgraduate School is providing technical consultation for specification and design of amphibious planning models for Marine Corps specific capabilities in the next-generation command staff training system, the Joint Simulation System (JSIMS). JSIMS will be used by the U.S. Marine Corps in joint exercises.

SUMMARY: The Naval Postgraduate School performed the following: 1) Specified user interface requirements for amphibious planning capabilities in USMC JSIMS relating to waterborne and helicopterborne ship-to-shore movements. 2) Reviewed and provided written comments on USMC JSIMS model expositions for Amphibious Operations, to include the Embarkation, Assault, Transition, and Retrograde models. 3) Attended and participated in selected requirements and design review meetings. Advise the SSC-SD USMC JSIMS Program Manager on progress, issues, and concerns with the development.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling and Simulation, Amphibious Operations, Joint Simulation System (JSIMS)

SCENARIO AUTHORING AND VISUALIZATION, PHASE 2

Curtis L. Blais, Research Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: To perform research and development on browser-based, graphical scenario authoring and exploration tools for ship-to-objective maneuver and other emerging USMC operational employment concepts. The authoring component will enable USMC subject matter experts, working alone or collaboratively as a team, to script a complex scenario in a virtual, extended, littoral battle space.

SUMMARY: Phase 2 work activities included:

- Investigation: Identified additional 3D models to be added to the object palette, including representation of control measures. Investigated representations for built-up areas and expanded warfare areas (e.g., communications and electronic warfare). Researched and identified approaches for embedding intelligent behavior into the scenario objects. Continued investigation of XML-based descriptions of the scenario and possible conversion to scenario input files for large-scale wargaming systems. Investigated architectural changes necessary to convert from DIS to the HLA for multi-user and distributed operation of the Scenario Authoring and Visualization tool (i.e., for collaborative authoring or multiple processor execution of the scenario).
- Design: Modified and developed tools and techniques to enhance authoring software architecture and to expand capabilities in warfare area and object representations.
- Development: Implemented software and tested for the new and modified functional capabilities. Created additional scenarios depicting the interplay of represented land, air, sea, and littoral objects and operations to support testing and demonstration of advanced features of the software. Included study of the interaction of operations with control measures.
- Demonstration: Provided a briefing of software architecture and capabilities at the DMSO Program Review in July 2002.
- Preparing final project software documentation and installation software for delivery to the sponsor and to the Marine Corps.
- Provided project status reporting and performed periodic in-progress reviews with participants and sponsor(s).

NPS faculty performed technical and contractual management, with participation of faculty and students in the engineering activities.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling, Simulation, Web 3D, Scenario, Generation, Web-Enabled Navy

MINE IMPACT BURIAL MODEL SENSITIVITY STUDY

Peter C. Chu, Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Oceanographic Office

OBJECTIVE: The Mine Impact Burial Model was developed by the Coastal System Station; subsequent upgrades have been made by the Naval Research Laboratory (NRL). Some of the major input parameters to the model are environment (sedimentation, shear strength, water depth), mine characteristics (shape, center of gravity, weight, and mine deployment parameters), deployment platform (ship, aircraft, submarine), speed of platform, angle of mine upon entering water, rotational velocity at time of deployment and others. The model has undergone limited validation in "R&D" experiments in which most input parameters were carefully measured or monitored. Many of the input parameters will never be known for operational mine deployments; thus, even if the model is accurate using 'perfect' input parameters, it may not be useful if mine impact burial is sensitive to parameters that are seldom known in practice. The purposes are to perform sensitivity tests with the burial model and to investigate the ocean environment of the east Asian marginal seas for mine burial prediction.

SUMMARY: Mine Drop Experiment (MIDEX) was conducted in June 2001 at the NPS swimming pool using 1/20th scale model mines. During the experiment, a three-dimensional hydrodynamic data set of the mine movement in water column was collected. This data was used to evaluate the Navy's Impact Burial Prediction Model (IBPM), which creates a two-dimensional time history of a bottom mine as it falls through air, water, and sediment. The output of the model is the predicted burial depth of the mine in the sediment in meters, as well as height, area, and volume protruding. Model input consists of environmental parameters and mine characteristics, as well as parameters describing the mine's release. The MIDEX data shows that the current IBPM model needs to be improved.

A new research program "Mine Burial Prediction" was initiated at ONR. As a leader for the impact burial team, NPS actively participated the program planning and experiment designing.

DoD TECHNOLOGY AREAS: Battlefield Environments, Environment Effects

KEYWORDS: Mine Burial, Shear Strength, Ocean Survey, Ocean Variability, Ocean Prediction

ASSESSMENT AND RECONSTRUCTION OF NAVY'S MINE IMPACT BURIAL PREDICTION MODEL

Peter C. Chu, Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research and Naval Oceanographic Office

OBJECTIVE: The ultimate goals are to substantially improve, quantitatively, the U.S. Navy's mine burial predictive capabilities and to provide a complete data set of mine movement in water phase and mine impact burial for model evaluation. The goals include development of a new mine impact burial model for improving Naval technical decision aids and involvement of NPS students' (U.S. Naval officers) thesis study for enhancing their combat effectiveness.

SUMMARY: Work completed:

- A synchronized data set of ocean environment (including waves, currents, and bottom shear strength) and mine burial depth was established on the base of the Mine Impact Burial Experiment (MIBEX).
- Mine Drop Experiment (MIDEX) was conducted in June 2001 at the NPS swimming pool with 1/20 scale model mines. Around 500 mine drops were completed with different mine parameters and drop conditions. Upon completion of the drop phase, the video from each camera was converted to digital format and a dataset for mine movement in the water column was established.
- Mine test experiment at Carderock was completed.
- The hydrodynamic system depicting the movement of rigid body (such as a mine) in the water column has been established on the base of balance of momentum and moment of momentum.
- Workshop was conducted on ONR Expert System Program on Mine Impact Burial Prediction at NPS on January 10, 2001. The MIBEX dataset was transferred to the ONR Expert System group.

The dynamic system (nine nonlinear equations) for the mine movement has potential impact on the nonlinear dynamics. The hydrodynamics of mine impact in water column can be applied to a general scientific problem of the fluid-rigid body interaction including stability and chaotic motion.

The datasets obtained from three consecutive experiments, MIBEX, MIDEX, and mine testing at Carderock, will impact the scientific and Naval mine warfare communities on the mine movement in the water column.

DoD KEY TECHNOLOGY AREAS: Battlefield Environments, Environment Effects

KEYWORDS: Mine Warfare, Hydrodynamic Theory

CAPTURING THE WEAPON SYSTEM R&D AND ACQUISITION EXPERIENCE FROM THE COLD WAR ERA

Phil E. DePoy, Director
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: Discussion of R&D and acquisition experience from the end of WWII until the end of the Cold War with former Naval Laboratory Directors and retired officers who were heavily involved in R&D and acquisition. In addition, a roundtable was held for students and faculty.

SUMMARY: Perhaps at no other period in the Navy's history has the adoption of new technology in the Navy been as pronounced and effective as during the Cold War throughout the fifty or so years following the end of World War II. Key factors in the Navy's ability to make such advances and the circumstances that led to such remarkable achievements were identified:

- Continuity of leadership, funding, and focus.
- Technical competence in Naval officers, the civil service, University labs and industry.
- The existence of discretionary funds in both industry and the government.
- Program managers who were successful and extremely focused, knowledgeable of the technical details of their programs, and were, in effect, their own chief engineers.
- An emphasis on results rather than cost, mutual trust and respect, and a sense of urgency backed up by the courage of convictions.
- The existence of a defined potential enemy created a rather stable funding environment.
- A strong uniformed leadership, with rank aligned with responsibility, for those officers who dealt with the OSD and Congress.
- The in-house laboratories played an important role as honest brokers and keepers of the technical safety net.
- The best leaders, in both industry and government, were those who were rotated through both experiential and educational assignments such that they developed an understanding of the Navy and industry from a corporate sense.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Other (Acquisition)

KEYWORDS: Acquisition, Manpower, Personnel and Training

DATA AND ANALYSIS FOR FLEET BATTLE EXPERIMENT

Shelley P. Gallup, Research Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Warfare Development Command

OBJECTIVE: Provide data capture, analysis planning and execution, and reporting for Fleet Battle Experiments.

SUMMARY: The Naval Warfare Development Command (NWDC), in cooperation with the numbered Fleets, plans and executes Fleet Battle Experiments (FBEs) through the Maritime Battle Center (MBC). IDSEA/MI develops plans for data collection and analysis design during experiment planning, and then conducts data collection and post-experiment analyses, including:

- Physical Experiment Planning
- Analysis Planning
- Fleet Coordination for Analysis
- Data Capture Planning
- Data Capture
- Analysis
- Quantitative Measures of Effectiveness
- Knowledge Management
- Reporting
- Workshop Planning and Execution
- Modeling and Simulation

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Human Systems Interface, Modeling and Simulation

KEYWORDS: Experimentation, Operations Analysis, Knowledge Management, Concept Based Analysis, Network Centric Warfare, Time Critical Strike, Maritime Access, Ballistic Missile Defense

FORCE PROTECTION LIMITED OBJECTIVE EXPERIMENTS

Shelley P. Gallup, Research Associate Professor
Gordon E. Schacher, Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: Plan, execute, and report findings from a series of Limited Objective Experiments (LOEs) directly related to the critical operational issue of Force Protection (FP).

SUMMARY: Force Protection (FP) is an identified Future Navy Capability (FNC), related specifically to the Navy's perceived future access mission. Recent events have underscored the need to understand and implement appropriate capabilities in FP. The LOEs are directed at understanding the means to utilize and enhance organic ship capabilities in a range of conditions, using information technologies.

The proposed Dynamic Port Assessment (DPA) provides timely and useful information directly to a Navy ship prior to visiting a specific port. Improved situational awareness capabilities combined with the DPA must be coordinated with defense in depth, other USN ships in port, innovation in the use of shipboard weapons capabilities, and host nations. This LOE series will result in the development and identification of processes and technologies that permit a coordinated and dynamic capability in FP. The FP LOEs will address the urgent operational requirements for Commander-in-Chief Pacific Fleet; develop a

"Community of Interest" and process to respond to emergent operational needs of Fleet Commanders; and design a "road ahead" for experimentation to address future FP scenarios.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Command, Control and Communications, Other (Experimentation, Force Protection, Operations Research)

KEYWORDS: Force Protection, Network Centric Warfare, Knowledge Management

ADAPTIVE ARCHITECTURES FOR COMMAND AND CONTROL

William G. Kemple, Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: To investigate adaptation in joint Command and Control (C2) architecture. To develop theories of C2, i.e., "congruence" of task organization. To use modeling to identify near-optimal organizational decisions for C2 tasks. To test the theories and models in a series of experiments. To support implementation of adaptable C2 architectures.

SUMMARY: Basic research activities related to adaptive command and control occurred in three phases. The first two phases (a concept experiment and scenario pilot testing) were preparatory for Experiment 8, which is the culmination event for FY02. The focus of Experiment 8 (August 2002) is to design two distinct organizations and create two distinct task/resource requirements that would allow the examination of performance and processes in two conditions: 1) where the organization structure was congruent with the task requirements, and 2) where the structure was incongruent. The Concept Experiment 8 conducted in Fall 2001 focused on the preliminary evaluation of two structures (divisional and functional) with a single scenario that emphasized time-critical tasks. The pilot testing conducted in Winter 2002 examined two significantly revised scenarios. The revisions incorporated a series of offensive "mission tasks" that were integrated with the time critical tasks used on Concept 8 experiment. The two scenarios were also designed such that the task requirements would be more readily accomplished by one structure (e.g., divisional) and hypothetically be more challenging for the other structure (e.g., functional).

DoD KEY TECHNOLOGY AREAS: Human Systems Interface

KEYWORDS: Command and Control, Joint Operations, Organizational Experience

ADVANCED COMMAND AND CONTROL (AC2) RESEARCH SUPPORT

William G. Kemple, Associate Professor
Susan Hocevar, Assistant Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Chief of Naval Operations (N6)

OBJECTIVE: The purpose of this research is to advance our understanding of the implications of network centric operations to command and control. This will be accomplished through an integrated experiment process that links advanced concept seminar-type wargames with simulation-based wargame experiments. OPNAV N6 has identified particular areas of interest to include: Highlight risks and opportunities for C2, explore unintended consequences, identify guiding principles (i.e., rules, models, metrics), clarify and articulate assumptions and relevant uncertainties.

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

KEYWORDS: Command and Control, Modeling and Simulation

CENTER FOR DEFENSE TECHNOLOGY AND EDUCATION FOR THE MILITARY SERVICES (CDTEMS)

William G. Kemple, Associate Professor
Sue Hutchins, Research Assistant Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: U.S. Joint Forces Command

OBJECTIVE: To conduct investigations and participate in activities that support joint experimentation and enhance joint capabilities.

SUMMARY: The project team fielded a group of thirteen observer/analysts for Global 2000. The NPS team provided daily and post-game input to the J9 team and administered two surveys. In conjunction with NWDC, a concept for the ETO-to-Actions LOE was developed and conducted. The NPS team served as the lead for training and analysis. The project continued with the follow-on workshop on synchronization and effects assessment.

Planning for the final phases of the Peer-to-Peer (P2P) Wireless LOE was completed. New applications were developed to enable players with COTS PDAs (iPaq) to automatically report their location and to display the locations of all such equipped players on an electronic map.

The NPS team initiated the generation of a web-based 3D representation of the LOE area and events, which can be viewed in collaborative, networked environments. Under other funding, this technology is also being applied to support after-action review in Force Protection LOEs and may be a subject of a future LOE for evaluation of web-based 3D visualization for collaborative mission planning. Agent-based applications were also developed to allow monitoring and repair of the wireless network.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Joint Warfare, Joint Experimentation, Knowledge Experimentation, Experimentation Courseware, Concept Modeling, Simulation, Information Warfare and Operations

NAVAL POSTGRADUATE SCHOOL EFFORT TO SUPPORT GLOBAL WARGAME 2001

William G. Kemple, Associate Professor
Sue Hutchins, Research Assistant Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: NPS support for global wargame 2001 will consist of two components. The first component involves direct support to advancing A2C2 research; the second involves providing support to the joint force command J9 effort.

DoD KEY TECHNOLOGY AREAS: Other (Information Technology)

KEYWORDS: Network-Centric Operations, Operational Decision Making, Knowledge Wall

PERFORMANCE AND RISK ASSESSMENT OF FUTURE FORCE STRUCTURES - CALIBRATION EXPERIMENTS

Michael E. Melich, Research Professor
Rodney Johnson, Visiting Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Defense Advanced Research Project Agency

OBJECTIVE: Develop parameterization of basic radar-based air defense systems in co-evolution with a missile or aircraft based strike system, and estimate the required computing resources as a function of system complexity and level of detail modeling.

SUMMARY: Background of the proposed work was the identification by the investigators of four fields that in combination have the potential to lead to better ways to conceptualize, describe, assess, and integrate force projections and to generate alternative development trajectories: (1) the Living Systems Theory (LST) of James G. Miller; (2) portfolio risk assessment as applied to military R&D; (3) Evolutionary Computation; and (4) Distributed-object modeling. The focus of the work is to exercise the methods on a technically challenging but circumscribed example of a system development problem: the performance/risk analysis of a conceptual future air defense system in coevolution with a conceptual future air strike system. The work ties in with NPS work on bistatic radar systems using satellite-based illuminators.

Proposed tasks include: (1) select and parameterize performance measures for bistatic radar design; (2) perform test runs for bistatic problem; measure resource utilization; (3) perform preliminary LST analysis of development of an air defense system in coevolution with an air strike system-identify risk measures; (4) prepare progress report briefing; (5) estimate resources for applying proposed methods to air defense system development problem; (6) hold meeting of experts in portfolio analysis, risk assessment, and option pricing; (7) prepare final Phase 1 report.

DoD KEY TECHNOLOGY AREAS: Other (Force Planning)

KEYWORDS: Strategic Planning, Technological Forecasting

PERFORMANCE AND RISK ASSESSMENT OF FUTURE FORCE STRUCTURES - COEVOLVED INVESTMENT TRAJECTORIES, POM EXPERIMENTS

Michael E. Melich, Research Professor
Rodney Johnson, Visiting Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Defense Advanced Research Project Agency

OBJECTIVE: This work continues DARPA funded research begun in April 2000 under the same title. Results achieved in coevolving algorithms for playing the "POM" game will be expanded to include more realistic investment problems.

SUMMARY: The TEMPO Military Planning game is a game of resource allocation used in courses by the Defense Resources Management Institute (DRMI) as a vehicle for introducing concepts of modern defense management. Teams of players compete in building force structures by dividing limited budgets, over a succession of budgeting periods, between categories such as "acquisition" and "operation" of "offensive units" and "defensive units." The rules' apparent simplicity is deceptive: they pose challenging and difficult decision problems. Methods of Evolutionary Computation (EC) have been applied in developing programs for playing games ranging in complexity from tic-tac-toe to checkers. The proposal is to study issues involved in using evolutionary methods to develop computer programs capable of playing the TEMPO game and in extending the results to more realistic and complex problems of resource allocation-that is, to explore the feasibility of using computational power to discover effective resource-allocation strategies. The following issues are to be addressed: (1) scalability; (2) representation of "individuals" (candidate game-players); (3) coevolution (including the ability to generalize from the (symmetric) TEMPO game to non-symmetric situations; (4) introduction of new budget categories. This is a collaborative effort with

Professor Zbigniew Michalewicz (University of North Carolina at Charlotte; NuTech Solutions, Inc.) and others at NuTech.

DoD KEY TECHNOLOGY AREAS: Other (Force Planning)

KEYWORDS: Strategic Planning, Technological Forecasting, Evolutionary Computing

TEST OF DESIGN OF SPARSE OPTICAL ARRAY USING EVOLUTIONARY COMPUTATION

Michael E. Melich, Research Professor
Rodney Johnson, Visiting Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Research Laboratory

OBJECTIVE: To determine the applicability of evolutionary computing techniques to the design of a partially filled optical aperture intended to be used for imaging.

SUMMARY: "Evolutionary Computation" refers to a family of related approaches to complex computational problems that are finding a wide range of applications to design, optimization, classification, search, and adaptive control. These methods are based on ideas from biology: Darwinian natural selection and survival of the fittest. The context of the proposed work is a larger study of the application of evolutionary and other methods to force structure planning, including the use of evolutionary computation for the conceptual design of weapon system components. In previous work, the investigators had successfully applied evolutionary computation to a problem in phased-array radar antenna design.

The proposed work is a preliminary exploration of the use of evolutionary computation in the design of sparse optical arrays for imaging, e.g. in satellite applications. The work comprises three tasks of which the first is: (1) set up the geometries and representations for the optical aperture; design algorithms and specify "fitness functions." The "fitness function" is the figure of merit to be optimized by a design. Informally, the criterion for an optical array is that a quantity known as the optical transfer function should provide "good coverage" in the domain of spatial frequencies. In the absence of an accepted explicit analytical definition of "good coverage" it was decided to accommodate the use of several plausible "fitness functions" to permit comparison of the designs resulting from each. The second and third tasks are: (2) run the algorithm to generate candidate designs and prepare an annotated briefing of the results; (3) present results to designated representatives of the sponsor.

DoD KEY TECHNOLOGY AREAS: Sensors, Computing and Software

KEYWORDS: Evolutionary Computing, Optical Aperture Design

TECHNOLOGY ASSESSMENT AND ANALYSIS FOR AREA DENIAL

John Osmundson, Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Warfare Development Command

OBJECTIVE: Analyze technologies that might be available in the 2015 timeframe to be used to deny access of the U.S. Navy to world areas.

SUMMARY: Four phases: 1) identify hostile innovative technologies that have the capability to deny the U.S. Navy access to areas of potential conflict, 2) analyze and assess anti-access technology and compare with intelligence assessments, 3) reconcile Science and Technology plan with anti-access technology and identification of appropriate MOEs and MOPs, and 4) clarify results and address open issues.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Other (Sub-surface, Surface, Air, Space and Cyber Warfare)

KEYWORDS: Area Denial, Red Cell, Innovation Technologies

SUPPORT FOR CONCEPTS TO TECHNOLOGIES FY-01 (CONTECH 01) MINE COUNTERMEASURES (MCM) WARGAME

Clyde L. Scandrett, Associate Professor
John D. Pearson, Chair of Mine Warfare
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: This proposal will provide the FY 01 funding segment for the Office of Naval Research (ONR) sponsored concepts to technologies (CONTECH) wargame series. This wargame series directly supports the ONR future Naval capabilities program in the area of mine countermeasures (MCM).

DoD KEY TECHNOLOGY AREAS: Other (Mine Countermeasures)

KEYWORDS: Future Naval Capabilities, CONTECH Wargames, MCM

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Faculty Publications and Presentations

JOURNAL PAPERS

Chu, P.C., Lan, J. and Strauhs, H., "A Numerical Simulation of the Japan/East Sea (JES) Seasonal Circulation," *Estuarine and Coastal Modeling, 6*, American Society of Civil Engineering, pp. 94-113, 2000.

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Bordetsky, A. and Branstetter, T., "Collaborative Technology for Multinational Peace Operations Experimentation," NATO Multinational Experimentation Symposium, Oslo, Norway, September 2001.

Chu, P.C., "Hydrodynamic Theory of Mine Impact Burial," ONR Mine Burial Prediction Science Program Impact Burial Workshop, Crystal City, VA, 14-15 November 2000.

Chu, P.C., "Mine Impact Burial Model and Data Comparison," ONR Expert Systems Modeling Workshop, Monterey, CA, 10 January 2001.

Thate, T., "Identifying Collaborative Tools for Combined Joint Task Force 'Focused Logistics' to Support 'Rapid Decisive Operations'," The Fourth International Conference on Electronic Commerce Research (ICECR-4), Dallas, TX, 8-11 November 2001.

TECHNICAL REPORTS

Buettner, R., "Information Operation/Information Warfare Modeling and Simulation," Naval Postgraduate School Technical Report, NPS-IJWA-01-001.

Chu, P.C., Cintron, C.J., Haeger, S.D., Fox, D.N. and Keenan, R.E., "Yellow Sea Mine Hunting Using the Navy's Cass/Grab Model," Naval Postgraduate School Technical Report, NPS-IJWA-01-016.

Chu, P., Smith, T.B. and Haeger, S.D., "Mine Burial Impact Prediction Experiment," Naval Postgraduate School Technical Report, NPS-IJWA-01-007.

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Gaver, D.P. and Jacobs, P.A., "DISC-O-TIC: A Discrete-Time Analytical Meta-Model for Use in Combat Systems that Utilize High Resolution Simulation Models," Naval Postgraduate School Technical Report, NPS-IJWA-01-009.

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CONTRIBUTION TO BOOKS

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THE MODELING, VIRTUAL ENVIRONMENTS AND SIMULATION (MOVES) INSTITUTE

MICHAEL ZYDA
DIRECTOR

MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION

OVERVIEW:

Our mission is research, application and education in the grand challenges of Modeling, Virtual Environments and Simulation (MOVES).

The MOVES Institute operates independently and in collaboration with various U.S. Navy and defense modeling and simulation centers to:

- Carry out basic and applied research
- Analyze continuing modeling, virtual environments and simulation programs
- Create advanced prototypes
- Develop real technologies and applications for the defense community

CURRICULUM SERVED:

- Modeling, Virtual Environments, and Simulation

DEGREE GRANTED:

- Master of Science in Modeling, Virtual Environments and Simulation

FACULTY EXPERTISE:

- Virtual Environments:
  Professor Michael Zyda, Military Instructor CDR Russell Shilling, Lecturer Perry McDowell, Senior Lecturer John Falby, Associate Professor Rudolph Darken, Professor Peter Chu, ResearchAssistant Professor Michael Capps, and Associate Professor Donald Brutzman
- Modeling Simulation:
  Research Associate Professor Wolfgang Baer, Research Associate Curtis Blais, Professor Gordon Bradley, Distinguished Professor Donald Gaver, Research Professor John Hiles, Professor Patricia Jacobs, Associate Professor Thomas Lucas, Associate Professor Neil Rowe, Professor James Taylor, and Associate Professor Xiaoping Yun
- Human Factors:
  Research Assistant Barry Peterson, Professor Robert McGhee, Lecturer Eric Bachmann, Associate Professor Rudolph Darken
- Security:
  Associate Professor Cynthia Irvine
- Communications/Networks:
  Assistant Professor Geoffrey Xie and Professor Nancy Roberts

RESEARCH THRUSTS:

3D VISUAL SIMULATION

- **3D Visual Simulation** - Virtual naval gunfire support. Immersive ship walkthroughs - damage control virtual environments. Littoral zone warfare. Building and Urban Walkthroughs - urban warfare, hostage extraction, operations other than war. Ocean environment tactical visualization. C4I/IW information visualization. Game-engine utilization and handheld visual simulation delivery systems. Synthetic ocean environment simulations.
- **XML/X3D** - Use of Extensible Markup Language (XML) for deploying 3D M&S products over DoD messaging systems, creating interoperable behavior streams, gaining database schema interoperability, and defining ontologies for software agent interactions compatible with deployed C4I and combat control systems.

NETWORKED VIRTUAL ENVIRONMENTS

- **Multicast and Area of Interest Managers** - Software architectures for facilitating the development of large-scale, media-rich, interactive, networked VEs.
- **High Bandwidth Networks** - Experimentation and utilization of next-generation Internet technologies for large-scale, networked virtual environments, and collaborative M&S development and application.
- **Wireless** - Handheld delivery systems.
- **Latency-reduction** - Techniques for predictive modeling in distributed simulations.
- **VE Architectures for Interoperability** - Network software architectures for scalability, composability and dynamic extensibility.
- **Standards for Interoperability** – High Level Architecture; Next Generation RTI; Web-based interoperability. Standards for streamed interactive 3D as an automatically created component for joint message systems. Guiding M&S standards interoperability efforts with the Web3D Consortium, World Wide Web Consortium and MPEG4 Streaming Group.

COMPUTER-GENERATED AUTONOMY

- **Agent-based Simulation** - Computer-generated characters that accurately portray the actions and responses of individual participants in a simulation. Adaptability - computer generated characters that can modify their behavior automatically. Learning - computer generated characters that can modify their behavior over time. Organizational modeling.
- **Story Line Engines** - Content production and simulation prototyping. Technologies for autonomous, real-time story direction and interaction.
- **Human Representations and Models** - Authentic avatars that look, move, and speak like humans.
- **Modeling Human and Organizational Behavior** - Integrative architectures for modeling of individuals, including neural networks; rule-based systems, attention and multitasking phenomena, memory and learning, human decision-making, situation awareness, planning, behavior moderators, modeling of behavior of organizational units, modeling of military operations, and modeling of information warfare.

HUMAN-COMPUTER INTERACTION

- **Training in the Virtual Environment** - Fidelity requirements for wayfinding in the virtual environment. Developing virtual environments for training. Evaluating virtual environments for their utility in training.
- **Intelligent Tutoring Systems** - Developing experts via the use of computer-based virtual environments.
- **Human Factors in Virtual Environments** - Multimodal interfaces, task analysis, spatial orientation and navigation, performance evaluation, interaction techniques, interaction devices, virtual ergonomics, cybersickness, usability engineering, training transfer, human perception.

TECHNOLOGIES FOR IMMERSION

- **Image Generation** - Real-time, computer graphic generation of complex imagery, HDTV, DVD, next generation delivery systems, novel display technologies, handheld and body-worn devices.
- **Tracking** - Technologies for keeping track of human participants in virtual environments.
- **Locomotion** - Technologies that allow participants to walk through virtual environments while experiencing hills, bumps, obstructions, etc.
- **Full Sensory Interfaces** - Technologies for providing a wide range of sensory stimuli: visual, auditory, olfactory, and haptic.
- **Novel Sound Systems** – The generation and delivery for both interactive and recorded media. Spatial sound. Immersive sound and psychoacoustics.

DEFENSE AND ENTERTAINMENT COLLABORATION

- **Technology Transition** - Adapt technologies and capabilities from the entertainment industry.
- **Game-Based Learning** - Distance learning via the use of game technology and development.
- **Internet and Game Delivery Systems** - SimNavy, Army Game Project, SimClinic, SimSecurity.

NEXT GENERATION MODELING

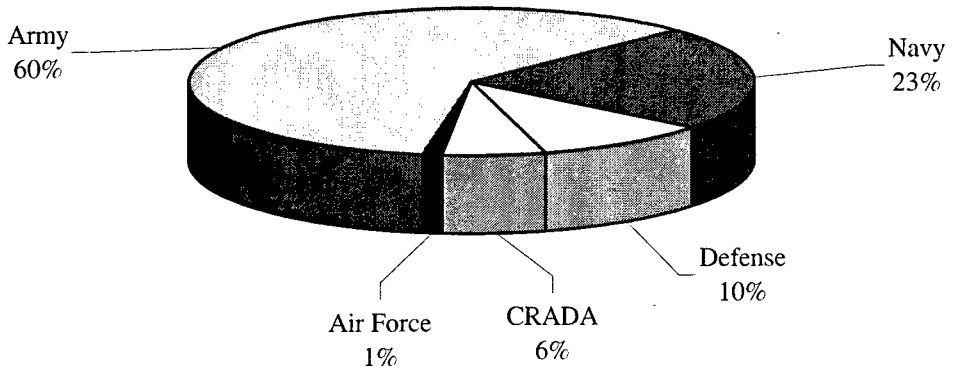
- **Modeling and Simulation** - Dynamic and state space modeling for information warfare and information operations. High-resolution combat models. High-level aggregate models. Network centric warfare. Agent-based simulation. Physically-based modeling to insure physical realism underlies the VR. Theater, tactical and campaign level modeling. Sensor modeling. Architectures for future combat modeling systems.
- **Navy Cyberspace** - Full end-to-end simulation of the ocean environment including subsurface surface, air and space. Oceanographic data sets and models. Tactical databases. Interoperability with live ship tracking message systems. Reusable, in the small or in the large, by fleet assets. Underwater robots. Interoperability with global command and control systems.
- **Current Programs in Combat Modeling** – JSIMS Maritime Battlespace, Naval Simulation System, JSIMS, JWARS, JMASS, OneSAF, HLA, Computer-Generated Forces.

TECHNOLOGY TRANSITION

- Technology transition is part of the MOVES Institute. CRADAs with industry are encouraged as well as the licensing of institute generated intellectual property.

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 Modeling, Virtual Environments and Simulation Institute is provided below:



Size of Program: $3855K

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GENERIC HUB: XML-BASED INFORMATION INTERCHANGE FOR DEFENSE MESSAGING, SHIPBOARD/THEATRE COMMAND AND CONTROL

Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Undersea Warfare Center - Newport Division

OBJECTIVE: NPS will support and verify IDA conversion of the LC21EDM Data Model to an XML-based schema representation, and further support NUWC efforts to map LC21EDM, DIS and X3D/VRML to shipboard combat control systems. Finally NPS will provide an exemplar amphibious raid operations order in XML along with improved XML-based 3D virtual environment autogeneration. NPS has long been a leader in exploring new technologies for large-scale virtual environments and DoD distributed simulation. Recent results in extensible 3d (X3d) graphics and WEB3D GEOVRML have enabled wide-scale distribution of georeferenced 3D scenes. The NPS DIS-JAVA-VRML working group has further produced a georeferenced 45KM X 55KMM battlespace for Fort Irwin, CA, along with distributed interactive simulation (DIS) networking. NPS work has further shown that XML-based military operation orders can automatically generate matching 3D virtual environments. We proposed to generalize "lessons learned" from these recent successes in support of the generic HUB project, in partnership with NUWC and Institute for Defense Analysis (IDA), for prime sponsor office of Secretary of Defense (OSD).

DoD KEY TECHNOLOFY AREAS: Modeling and Simulation, Command, Control and Communications

KEYWORDS: Shipboard Command Control Systems, Virtual Environments, XML-based Military Operations Orders

OPERATIONS INTEGRATION WORKING GROUP (OIWG) PARTICIPATION

Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Sea Systems Command

OBJECTIVE: This proposal supports Dr. Brutzman's attendance at monthly meetings of the OIWG at Submarine Development Squadron Twelve, Groton, CT and other facilities. The Navy is conducting the Advanced Tactical Build (ATB) project to infuse advanced tactical control technology into submarine combat subsystems. An ATB consists of tactical decision aids that assist the Commanding Officer in achieving control of the tactical situation and making timely tactical decisions. The Operations Integration Working Group (OIWG) is part of the tactical control development-working group, and evaluates current work and provides peer review of ATB projects.

As part of the various OIWG evaluations, he will provide expert advice on information display technology and designs, particularly with respect to interactive 3D graphics and scientific visualization of sonar sensors. Naval officer students at NPS will also participate in these efforts, through course work and thesis research evaluating the effectiveness of cutting-edge ATB tactical displays and algorighms. NPS will also produce a prototype tactical-visualization training system, illustrating the effective use of 3D graphics for periscope observations and visual contact recognition.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Advanced Tactical Build, Tactical Decisions

SCENARIO AUTHORING AND VISUALIZATION, PHASE 2

Donald Brutzman, Associate Professor
Curtis L. Blais, Research Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: The purpose of this scenario authoring and visualization project is to perform research and development on browser-bases, graphical scenario authoring and exploration tools for ship to objective maneuver and other emerging USMC operational employment concepts. The authoring component will enable USMC subject-matter experts, working alone or collaboratively as a team, to script a complex scenario in a virtual extended littoral battlespace.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Modeling, Simulation, WEB3D, Scario, Generation

STREAMING 3D GRAPHIC USING VRTP FOR DISTRIBUTED SIMULATION

Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Sea Systems Command

OBJECTIVE: NPS and the George Mason University (GMU) C3I Center networking and simulation laboratory have been leaders in exploring new technologies for DoD distributed simulation. Both groups have worked the areas of virtual environments, network protocol support and multiplatform software tools based on Web browsers and JAVA.

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

KEYWORDS: Virtual Environments, Network Protocol Support, Multi-platform Software Tools

SOFTWARE FRAMEWORK FOR COMPOSABLE AND SECURE VIRTUAL ENVIRONMENTS

Michael V. Capps, Research Assistant Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Secretary of the Air Force

OBJECTIVE: It is proposed to develop a systems architecture to support composable and extensible immersive virtual environments. This framework will allow development JOF Novel applications in the intelligence domain, both through composition of existing programs and rapid development of new applications. Additionally, this platform will be used to explore new methods for security in virtual world telecollaboration.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Synthetic Environments, Virtual Environments, Modeling and Simulation

SOFTWARE FRAMEWORK FOR LARGE-SCALE VIRTUAL ENVIRONMENTS SUPPORTING SITUATED COGNITIVE AGENTS

Michael V. Capps, Research Assistant Professor
Rudolph P. Darken, Assistant Professor
Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Undersea Warfare Center - Newport Division

OBJECTIVE: To develop a large-scale virtual environment framework capable of supporting situated cognitive agents, the framework to allow rapid development of complex VE applications for training and simulation.

SUMMARY: The NPSNET Research Group has designed the architecture of the NPSNET-V system (http://movesinstitute.org/~npsnet/v) to construct a practical working platform for research on infrastructure technology for networked Virtual Environments (VEs). NPSNET-V is the first VE system that offers a tangible demonstration of the benefits of dynamic extensibility and composition in VEs.

NPSNET-V allows the addition of application components during runtime, thereby lending new functionality to a VE. Users can load these components, which consist of Java classes, from disk or the network using standard Java class loading mechanisms. In the same manner, users may discover new types of entities during runtime. The first time a client encounters an entity type, it has only to download its description and create an instance. In this way, simple client applications are dynamically extended to understand new environments and entities as they become available. These capabilities apply to all facets of VE architecture, including communications and even system control protocols.

This is a multi-year project, funded by the CRR and the MOVES Institute. Second year tasks included a series of networked graphical demonstrations and VE architecture based on a minimal kernel.

PUBLICATIONS:

Salles, E., et al, "Security in Run-Time Extensible Virtual Environments," *Proceedings of the 2002 IEEE Workshop on Information Assurance*, United States Military Academy, West Point, NY, June 2002.

THESIS DIRECTED:

Washington, D., "Implementation of a Multi-Agent Simulation for the NPSNET-V Virtual Environment Research Project," Masters Thesis, Naval Postgraduate School, September 2001.

Wathen, S., "Dynamic Scalable Network Area of Interest Management for Virtual Worlds," Masters Thesis, Naval Postgraduate School, September 2001.

Salles, E., "Security in Run-Time Extensible Virtual Environments," Masters Thesis, Naval Postgraduate School (in progress)

DoD KEY TECHNOLOGY AREA: Computing and Software, Modeling and Simulation

KEYWORDS: Virtual Environments, Networking, Simulation, Virtual Reality

NAVIGATION PERFORMANCE ENHANCEMENT IN EXPEDITIONARY WARFARE MISSION PROFILES

Rudolph P. Darken, Associate Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of Naval Research

OBJECTIVE: The three focal application areas within the research plan will require delving deeply into basic research issues of (1) cognitive and behavioral modeling, (2) enhancing component spatial skills, and (3) spatial knowledge acquisition. The objective is to investigate the nature of the basic building blocks of these highly aggregated military tasks in order to determine how best to apply technology to specific training needs of modern expeditionary warfare. It is believed necessary to embed this research program in a deep understanding of the problem domain to include extensive field study with sailors and Marines. The specific attributes of the target population are likely to be significantly different than those of the population at large.

The research plan relies heavily on an integrated effort of modeling and empirical experimentation. It should be understood that these are considered to be parallel rather than sequential tasks, beginning with descriptive modeling, possibly including ethnographic techniques. This results in a framework within which experimentation can be structured. Results from the experimentation can then be fed back into the modeling process as construction begins on computational models of navigation. This is an important step that has been struggled with extensively in the past. Learning from the fleet indicates that many navigation tasks are trained via OJT (or on-the-job-training). While it is not foreseen to replace OJT with VE training, VE could be used to enhance OJT methods. This requires an understanding of how these complex processes work, not merely a replication of reasonable expert navigation behavior as might be adequate for CGF (computer generated forces) type application. If a VE training system is to facilitate the training of expert navigation behavior, it needs to understand how experts navigate and be able to teach it. This is the motivation for computation models of human navigation.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Virtual Environments, Modeling and Simulation, Manpower, Personnel and Training

MANPOWER OPTIMIZATION MODEL FOR MARINE FORCES PACIFIC

John Hiles, Research Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Marine Corps Combat Development Command

OBJECTIVE: Develop a preliminary design and development plan for a manpower optimization model. At the end of the period of work, the design and plan will be delivered.

DoD KEY TECHNOLGY AREAS: Manpower, Personnel and Training

KEYWORDS: Manpower, Modeling, Simulation

AUDIO TECHNOLOGY AND MANAGEMENT IN MODERN NAVY SYSTEMS

CDR Russell Shilling, USN, Military Faculty
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of Naval Research

OBJECTIVE: Develop and test advanced audio technology and an interactive audio management user interface for advanced operational Navy workstations and other Navy applications.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface

KEYWORDS: Audio Technology, Interactive Audio Management Users Interface

DEVELOPING AN AUDIOMETRIC MEASURE TO ASSESS LOCALIZATION PERFORMANCE FOR VIRTUAL ENVIRONMENTS AND SPATIALIZED AUDITORY DISPLAYS

CDR Russell Shilling, USN, Military Faculty
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of Naval Research

OBJECTIVE: The proposed project is a three-year effort. During the first year, various combinations of audio equipment will be evaluated to determine the appropriateness for use in spatialized audiometry tasks. In addition, appropriate psychophysical tasks will be identified for use in an audiometric test of headphone localization. Perceptual comparisons will be made between off-the-shelf audio equipment and specialized spatial audio equipment to determine whether off-the-shelf components will be adequate for testing localization ability. Companion systems will be created and data collected at Boston University with Barbara Shinn-Cunningham, a leading expert in spatial auditory perception. Aside from sharing equipment and travel expenses for consultation, the collaboration will be at no cost to the government. The second year's effort will use what is learned during the first year to revise the individualized head related transfer functions, and assess the effectiveness of the system. The third year will complete data collection, assemble libraries of highly localizable stimuli and Head Related Transfer Functions (HRTFs), and provide the software and techniques to interested researchers in the audiology and VE community.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Computing and Software

KEYWORDS: Spatialized Audiometry, Head Related Transfer Function

ARMY GAME PROJECT

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
John Falby, Senior Lecturer
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Office of the Assistant Secretary of the Army – Manpower and Reserve Affairs

OBJECTIVE: The Naval Postgraduate School Modeling, Virtual Environments and Simulation (MOVES) Institute proposes to develop instrumented, networked videogames to improve Army recruiting.

SUMMARY: The U.S. Army has a shortfall in recruiting. There is a potential for improving recruiting through the use of Web-based, instrumented, set of networking videogames or computer games (both of which are hereafter referred to as videogames).

The web-based videogames will: attract people to the Army, provide high fidelity feedback about potential recruits, obtain leads for recruiting, and deliver strategic communications about the Army to the potential recruit.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Synthetic Environments, Virtual Environments, Modeling and Simulation, Agent-Based Simulation, Defense and Entertainment

CONTEXT MACHINE - A DEVICE TO DETERMINE CONTEXT FROM SYMBOLIC INPUTS

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
Perry McDowell, Lecturer
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The purpose of the Augmented Cognition Program is to increase the information management capacity of the human-computer warfighting integral by developing and demonstrating quantifiable enhancements to human cognitive ability in diverse, stressful, operational environments of the U.S. warfighter by several orders of magnitude.

SUMMARY: The MOVES Institute at the Naval Postgraduate School is participating in the DARPA Augmented Cognition Program by creating the Context Machine to explore the notion of "context" in a general way, and to study how such a device might improve future warfighting capabilities. The user's current situation, such as their location, their objectives, and the presence of other people and objects, are inputs to the Context Machine. The machine uses the information to determine context. Based upon this context, it determines the best course of action to achieve the user's goals, which is then conveyed to the user. It is imperative that the assistance supplied by the Context Machine be appropriate to the situation, useful, and wanted.

The first step in this research was to identify those situations in which the Context Machine would prove most useful. Those situations are found when the user:

- Cannot understand information in the environment
- Cannot perceive certain information in the environment
- Does not have time to process information in the environment
- Can process the environment, but does not have time to communicate what has been processed.

The second step was to build a software platform for investigation into varying definitions of perception and cognition. A commercial game engine was selected, because of its ready availability from another project, its broad functionality, the ease with which it can be modified, and its reliance on commercial off-the-shelf hardware and software.

A software prototype was successfully constructed in which the Context Machine aids an infantryman on a clandestine reconnaissance mission. This demonstration was presented to the DARPA sponsor, as well as to numerous distinguished visitors to the Naval Postgraduate School.

As a result of these efforts, the project has been funded for an additional three years.

PUBLICATIONS:

McDowell, P., "A Taxonomy of Context Based Computing," (Paper in progress)

PRESENTATIONS:

Zyda, M. J., "Interest Management," Workshop on Perceptive User Interfaces, Orlando, Florida, 15 November 2001.

THESIS DIRECTED:

McDowell, P., "The Context Machine: A Device to Determine User's Context from Incomplete Data," Ph.D. Dissertation, Naval Postgraduate School, (in progress)

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control, and Communications, Computing and Software, Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual Reality, Augmented Cognition, Perception Modeling, Augmented Reality

ESTABLISHMENT OF AN ARMY VIDEO GAME

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of the Assistant Secretary of the Army for Manpower and Reserve Affairs

OBJECTIVE: To design, develop, test, install, maintain, and operate instrumented and networked interactive Army video games, for use on the Microsoft Windows system.

SUMMARY: 2001 was the second year of this five-year project. The initial software releases are planned for 2002, and therefore, this year was spent in research and development. Demonstrations of software progress were given to sponsor representatives at all levels, up to and including the Secretary of the Army.

The staff for this project consists of nearly 25 MOVES faculty, staff, and full-time on-site contractors. Student thesis research provides important input as well, and our graphics engine technology has provided a stable and full-featured platform for experimentation. Thesis topics are quite varied, which demonstrates the complex nature of this project; research areas include dynamic story creation, agent-based intelligence for infantry simulation, rendering algorithms for terrain geometry, and rotary-winged vehicle physics.

PUBLICATIONS:

Capps, M., McDowell, P., and Zyda, M., "A Future for Entertainment-Defense Research Collaboration," *IEEE Computer Graphics and Applications*, January/February 2001.

Capps, et al., "Gaming Techniques for Building Compelling Virtual Worlds," SIGGRAPH 2001, Los Angeles, CA, July 2001.

THESES DIRECTED:

Back, D., "Agent-Based Soldier Behavior in 3D Game Environments," Masters Thesis, Naval Postgraduate School, (in progress).

Buhl, C., "Defense-Entertainment Collaboration," Masters Thesis, Naval Postgraduate School, (in progress).

Osborne, B., "An Agent-Based Architecture for Guiding Interactive Stories," Ph.D. Dissertation, Naval Postgraduate School, (in progress).

Spears, V., "Terrain Level of Detail in First Person, Ground Perspective Simulation," Masters Thesis, Naval Postgraduate School, (in progress).

Perkins, K., "Implementing Realistic Helicopter Physics/Artificial Intelligence in 3D Game Environments," Masters Thesis, Naval Postgraduate School, (in progress).

EXPLAINATIONS USED IN TUTORING

Michael J. Zyda, Professor
Rudolph P. Darken, Associate Professor
Barry Peterson, Research Assistant
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Undersea Warfare Center and Defense Advanced Research Projects Agency

OBJECTIVE: Existing intelligent tutoring system (ITS) provide at best rudimentary explanations of the desired actions overall task performance. Such explanations play a key role in real interactions between a human student and tutor. Therefore, one potential way to improve the quality of training provided by ITS is

to incorporate explanations into the feedback that the virtual tutor provides that are based on the types of explanations that real tutors would give in that same scenario.

SUMMARY: To achieve that end, a Teo-Phase approach is proposed. First, field studies will be conducted to describe the behavior and role of explanation in real-world mentoring relationships. Second, this description will categorize and encode into a form amenable to a cognitive architecture

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computing, Intelligent Tutoring Systems, Cognition, Explanation

INTERNAL MOTION TRACKING TECHNOLOGY FOR INSERTING HUMANS INTO A NETWORKED SYNTHETIC ENVIRONMENT

Michael J. Zyda, Professor
Xiaoping Yun, Associate Professor
Barry Peterson, Research Assistant
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: U.S. Army Research Office

OBJECTIVE: This proposal requests continued support to develop an internal track body suit that is able to track the entire human body and to integrate the tracking data into a networked virtual environment. This body suit would require the construction of fifteen of the MARG sensors prototyped in the current effort.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface

KEYWORDS: Networked Synthetic Environment

SELF-LEARNING AUTONOMOUS AGENTS FOR DISTRIBUTED SIMULATORS

Michael J. Zyda, Professor
Michael Van Putte, Ph.D. Student
Brian Osborn, Student
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: This research proposes to develop a prototype self-learning multi-agent architecture adaptable to military situations. There is a potential for improving simulation realism, fidelity and overall effectiveness by developing a multi-agent based simulatios, populated with self-learning autonomous agents. This research proposes to develop a prototype self-learning multi-agent architecture adaptable to military simulations. Large scale distributed simulations play a vital role in every military planning. From the assessment of military hardware and evaluation of combat doctrine, to identifying computer security vulnerabilities and conducting rehearsal training, computer simulation is a fundamental resource for decision makers.

Self-learning agents in distributed simulations would provide the ability to explore the effects of a changing environment and potential impact of future technologies in military operations. Self-learning agents would themselves be able to explore and develop new procedures and identify vulnerabilities in response to changing capabilities and threats, moral and political constraints, and unit skill levels.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling and Simulation, Agent-based Simulation, Self-learning Autonomous Agent

THE MODELING, VIRTUAL ENVIRONMENTS AND SIMULATION (MOVES) INSTITUTE

2001
Faculty Publications and Presentations

JOURNAL PAPERS

Capps, M., McDowell, P., and Zyda, M., "A Future for Entertainment-Defense Research Collaboration," *IEEE Computer Graphics and Applications*, January/February 2001.

Morse, K. and Zyda, M., "Multicast Grouping for Data Distribution Management," *SIMPRA - Journal of Simulation Practice and Theory*, Fall 2001.

Yun, X.P., Bachmann, E.R., Suat, A., Akyol, K. and McGhee, R.B., "An Inertial Navigation System for Small Autonomous Underwater Vehicles," *Advanced Robotics*, Vol. 15, No. 5, pp. 521–532, October 2001.

CONFERENCE PAPERS

Bachmann, E., McGhee, R., Yun, X. and Zyda, M., "Inertial and Magnetic Posture Tracking for Inserting Humans Into Networked Virtual Environments," *Proceedings of ACM Symposium on Virtual Reality Software & Technology (VRST 2001)*, Banff, Alberta, Canada, pp. 9-16, 15-17 November 2001.

Darken, R., Kempster, K. and Peterson, B., "Effects of Streaming Video Quality of Service on Spatial Comprehension in a Reconnaissance Task," *Proceedings of I/ITSEC*, Orlando, FL, 2001.

Marins, J., Yun, X., Bachmann, E., McGhee, R. and Zyda, M., "An Extended Kalman Filter for Quaternion-Based Orientation Estimation Using MARG Sensors," *Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Maui, HI, pp. 2003-2011, 29 October-3 November 2001.

Peterson, B., Boswell, J. and Darken, R., "Collaborative Navigation in Real and Virtual Environments," *Proceedings of I/ITSEC*, Orlando, FL, 2001.

CONFERENCE PRESENTATIONS

Capps, et al., "Gaming Techniques for Building Compelling Virtual Worlds," SIGGRAPH 2001, Los Angeles, CA, July 2001.

Peterson, B., Boswell, J. and Darken, R., "Software Intensive System Integration," Monterey Workshop 2001, Monterey, CA, 19-21 June 2001.

Zyda, M., "The Future of Modeling, Virtual Environments and Simulation," IITSEC 2001, Orlando, FL, 29 November 2001.

Zyda, M., "The Future of Interactive Networked Entertainment," IITSEC 2001, Orlando, FL, 26 November 2001.

Zyda, M., "Interest Management," Perceptive User Interfaces Workshop, Orlando, FL, 15 November 2001.

Zyda, M., "Inventing Your Own Academic Degree and Research Institute," University of California Research Conference on Herding Cats, Moving Cemeteries, and Hauling Academic Trunks - Managing Change in Higher Education, UCLA Faculty Center, Los Angeles, CA, 19 October 2001.

Zyda, M., Panel on "The Future of Interactive Networked Entertainment," VSMM Conference, Berkeley, CA, 27 October 2001.

Zyda, M., "The MOVES Institute," Summer Computer Simulation Conference, Orlando, FL, 16-18 July 2001.

Zyda, M., "The MOVES Institute," MOVES Institute Open House, Naval Postgraduate School, Monterey, CA, 28 August 2001.

Zyda, M., "The Future of Modeling, Virtual Environments and Simulation," Summer Computer Simulation Conference, Orlando, FL, 16-18 July 2001.

Zyda, M., "Trends in Virtuality - Processors, 3D, Internet & Application," CIO Connect via Celebrity Speakers International, London, 12 June 2001.

TECHNICAL REPORTS

McGhee, R., Bachmann, E., Yun, X. and Zyda, M., *An Investigation of Alternative Algorithms for Singularity-free Estimation of Rigid Body Orientation from Earth Gravity and Magnetic Field Measurements*, Naval Postgraduate School Technical Report, NPS-MV-02-001, October 2001.

McGhee, R., Bachmann, E., Yun, X. and Zyda, M., *Real-Time Tracking and Display of Human Limb Segment Motions Using Sourceless Sensors and a Quaternion-Based Filtering Algorithm – Part I: Theory*, Naval Postgraduate School Technical Report, NPS-MV-01-001, November 2000.

PATENTS

Bachmann, E., McGhee, R., McKinney, D., Yun, X. and Zyda, M., "Method and Apparatus for Motion Tracking of an Articulated Rigid Body," Provisional Patent filed October 1999, final patent filed 30 October 2001.

CENTER FOR INTERDISCIPLINARY REMOTELY PILOTED AIRCRAFT STUDIES (CIRPAS)

ROBERT BLUTH
DIRECTOR

CENTER FOR INTERDISCIPLINARY REMOTELY PILOTED AIRCRAFT STUDIES

OVERVIEW:

The Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) is a research center at the Naval Postgraduate School, Monterey, California. CIRPAS provides Remotely-Piloted Aircraft (RPA) as well as manned aircraft services to the science, research, test and evaluation communities at the lowest practical costs. CIRPAS also provides an array of meteorological, aerosol and cloud particle sensors, data acquisition systems, calibration and data reduction service. CIRPAS conducts payload integration, reviews flight safety and provides logistical planning and support to research and test projects. CIRPAS also provides equipment and faculty which are used by NPS Departments for instruction purposes and supports research by faculty and students.

CIRPAS operates a variety of manned and unmanned air vehicles. The Common Ground Control Station (CGCS) is interoperable among the Center's various UAVs. CIRPAS can support a variety of payloads, data links and instrumentation to support user requirements. The facility has unique UAV flight services, which include:

- An available and centralized repository of diverse UAV assets to meet the needs of individual programs.
- Access to the UAVs and support equipment on a "lease" basis so the user is spared the cost of ownership.
- Turnkey UAV operations, including payload integration, flight safety and logistics support.
- Low cost services using shared assets.

CIRPAS provides cost effective flight services, which benefits a broad spectrum of research.

CIRPAS operates out of two facilities. The primary site is located near the NPS campus at the Marina Municipal Airport. This facility includes a 10,000 sq ft hangar, maintenance and administrative spaces for CIRPAS staff. These include a fully outfitted machine shop, electronics room and a calibration lab for the upkeep of scientific instrumentation. The second site is at McMillan Airfield, Camp Roberts, CA, 90 miles south of the Marina facility. The Camp Roberts site provides the Center with a base of operations for both manned and unmanned aerial vehicle (UAV) flight activities.

The California Institute of Technology supports CIRPAS as the prime contractor. It is also partners with NPS in providing the latest instrumentation for atmospheric research.

RESEARCH THRUSTS:

- Fleet and USJFCOM Exercises
- Support for CONOPS Development
- Atmospheric and Oceanographic Research
- Payload Test and Evaluation
- UAV Experimentation with Operational Forces supported by analysis provided by NPS Departments and Institutes

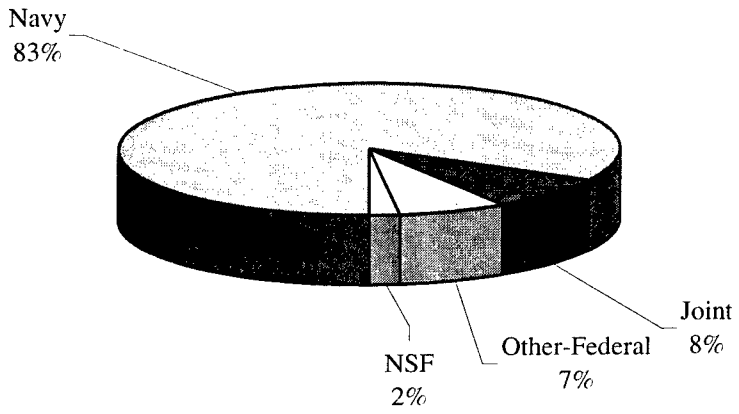
RESEARCH FACILITIES:

- Marina Facility
  - 10,000 sq ft maintenance hangar
  - 3000 ft runway – manned operations only
  - Naval Reserve Unit
  - Office space, flight operations
  - Maintenance facility
  - Payload development and integration
  - Logistics planning and support to research and test projects
- Camp Roberts Facility
  - Friendly airspace for testing and training (R2503)
  - Military ground maneuvers (equipment, personnel)
  - 3500 x 60 ft runway
  - 2000 sq ft hangar

- Shared utilization of NRL
- Temporary office space

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 Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) is provided below:



Size of Program: $5802K

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AURA ENGINEERING FLIGHT TEST SUPPORT

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Department of Energy

OBJECTIVE: Provide ALTUS UAV flight support for AURA project. Funds provided by DOE primarily support CIRPAS administrative functions and CIRPAS scheduled and unscheduled maintenance and flight operations.

SUMMARY: The Advanced UAV Remote-Sensing Applications (AURA) program is a Department of Energy funded UAV-based ultraviolet laser induced fluorescence (LIF) instrument currently being designed by Sandia National Laboratories. The instrument was flown on Altus. The purpose of the AURA test program is to verify the feasibility of LIF technology on an unmanned air vehicle platform. All flights were conducted out of Dugway's Michael Army Airfield and within Restricted Air Space R-6402A. 22.5 flight hours were flown in support of the AURA testing program.

DoD KEY TECHNOLOGY AREAS: Other (Remote Sensing)

KEYWORDS: LIDAR, Remote Sensing, UAV

CAMP ROBERTS OPS SUPPORT FOR NAVAL RESEARCH LABORATORY

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Naval Research Laboratory

OBJECTIVE: Support NRL UAV operations at CIRPAS airfield at Camp Roberts, CA.

SUMMARY: CIRPAS supported NRL's *Dakota* UAV flight activity at Camp Robert, McMillian Airfield for two years.

DoD KEY TECHNOOGY AREAS: Air Vehicles

KEYWORDS: NRL, Camp Roberts, McMillam Airstrip, UAV Technology

CARRIER AIR WING UAV FLIGHT SUPPORT

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Naval Strike and Warfare Center

OBJECTIVE: Provide MAE UAV flight support for CAG work-ups.

SUMMARY: Support Navy UAV CONOPS development activities at NAS Fallon with Predator and Altus UAVs. Predator operations included, voice relay, video closed captioning system, and RF link to NSAWC's operations center today, so that they can receive NPS/CIRPAS payload video during the flights.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: UAV, CONOPS, Predator

CIRPAS SUPPORT FOR NASA

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: CIRPAS supports NASA's Code Y UAV National Research Announcement (NRA) by providing development, evaluation support to potential proposers.

SUMMARY: UAV Facilitator Service to Proposers answer inquiries from potential NRA recipients about UAV capabilities, provide advice on UAV operational constraints, including regulatory constraints. Provide UAV vendor information and assist potential proposers in establishing contact with appropriate platform vendors. Maintain and update UAV technical information database based on data from vendors. Interface with other facilitators at Dryden Flight Research Center and Goddard Space Flight Center.

DoD KEY TECHNOLOGY AREAS: Other (Geophysics)

KEYWORDS: Environmental Scientific Investigation, UAVs, Program Support

KERNAL BLITZ 01 FLIGHT OPERATIONS SUPPORT

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research

OBJECTIVE: Provide *Pelican* flight support for AROSS operations in Kernel Blitz 01. CIRPAS provided 107 flight hours during a three-week mission window. Each sortie was no longer than eight hours per each 24-hour period.

SUMMARY: KB01 is a CINCPAC-sponsored training exercise involving 3DFLT and the First Marine Expeditionary Force (I MEF) forces. The exercise will simulate reestablishing freedom of navigation through the Straits of Catalina and clearing a conventional amphibious operating area in support of 1st Marine Expeditionary Brigade (MEB) operations. NPS/CIRPAS supported the Office of Naval Research (ONR), the Naval Surface Warfare Center (NSWC) during KB01 by providing payload integration, an airborne platform and crew for Arete` Associates' Airborne Remote Optical Spotlight System (AROSS). The experiment took place off the coast of southern California near Camp Pendleton and La Jolla, CA in the Kernel Blitz area of operations. Areté provided AROSS operators, analysts and engineers to support flight operations, conduct data collection, provide data analysis and produce Mine-Like Object (MLO) detection and Meteorological/Oceanographic (METOC) products. Real-time transmission of AROSS imagery and metadata was achieved through a collaboration with NSWC. The objective for the Kernel Blitz support were to demonstrate timely response to Fleet MLO and Meteorological/Oceanographic (METOC) requirements for mine countermeasures and battlespace characterization in support of Ship-to-Objective Maneuver amphibious operations. The Kernel Blitz 01 deployment to McClellan-Palomar Airport in Carlsbad, CA occurred 16 – 31 March 2001.

DoD KEY TWCHNOLOGY AREAS: Other (Mine Detection)

KEYWORDS: Pelican, AROSS, Kernel Blitz, Mine Detection

NAVAL POSTGRADUATE SCHOOL /CIRPAS SUPPORT OF NAVSEA UAV COMRELAY DEMONSTRATION

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Naval Sea Systems Command

OBJECTIVE: Naval Postgraduate School Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) provided flight operations support for the NAVSEA UAV COMRELAY Demonstration with the operation of CIRPAS UV-18A research aircraft. CIRPAS carried relay radio equipment aloft and demonstrate the benefits of UAVs as communications relay platforms in support of Marine Corps operations.

DoD KEY TECHNOLOGY AREAS: Other (Flight Operations)

KEYWORDS: Flight Operations, NAVSEA UAV COMRELAY

PREDATOR FLIGHT OPERATION AT CHERRY POINT, NC FOR JTFEX01-3

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: U.S. Joint Forces Command

OBJECTIVE: Support Joint Forces Command Predator MAE UAV flight operations at Cherry Point, NC for JTFEX-01-3. CIRPAS provided 30 flight hours over an 8-day mission window with level IV or less operations dependent on specific level of TCS status.

SUMMARY: CIRPAS provided UAV imagery support to the Time Critical Targeting (TCT)/Time Critical Strike (TCS) portion of the JTFEX01-3 exercise. TCT/TCS is a JFCOM-directed 'experimental' adjunct to the JTFEX series and overlays and integrates with the primary mission of the JTFEX - to train deploying Carrier Battle Groups (CVBGs) and Amphibious Ready Groups (ARGs). The TCT/TCS goal is to blend the intelligence process with the targeting process and identify shortfalls in DOTMLPF for time critical strike operations. Naturally, the forces available to participate in and support TCT/TCS each JTFEX varies. UAVs have not been a regular player in JTFEXs, and CIRPAS provides for that eventuality.

DoD KEY TECHNOLOGY AREAS: Other (UAV Technology)

KEYWORDS: Predator, UAV, JFC, JTFEX01-3

PREDATOR FIGHT OPERATION AT WEBSTER FIELD FOR AUVSI DEMO

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Naval Air Systems Command

OBJECTIVE: Support PMA-263 predator MAE UAV flight operations at Webster field, Patuxent River, MD for AUVSI demonstration. CIRPAS provided flight support over a one-day mission window.

SUMMARY: CIRPAS provided Predator flights at Webster Field, MD. Due to the low ceiling Predator was close to the airfield during the air show. CIRPAS provided a video feed to the crowd via a 50 ft jumbo screen for the entire show. At the conclusion, an imagery show was presented.

DoD KEY TECHNOLOGY AREAS: Other (UAV Technology)

KEYWORDS: Predator, UAV, PMA-263, AUVSI

PRAIRIE DOG II UAV FLIGHT SUPPORT

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Tactical Exploitation of National Capabilities (TENCAP) Office

OBJECTIVE: Provide ALTUS UAV flight support for Prairie Dog II. CIRPAS provided ALTUS UAV flight support for Prairie Dog II. CIRPAS provided 40 ALTUS flight hours during a two-week mission window. Each sortie was no longer than eight hours per each 24-hour period.

SUMMARY: Prairie Dog II is a Navy TENCAP-sponsored signals intelligence (SIGINT) payload similar in function to the Radiant Copper payload flown on Predator P030 at NAS Fallon in September 1999. The WESCAM 14TS/QS payload was integrated into the Altus ST UAV to image the target once it had been geolocated. The Prairie Dog II deployment occured at Camp Pendleton, CA.

DoD KEY TECHNOLOGY AREAS: Other (UAV Technology)

KEYWRODS: Prairie Dog II, ALTUS, UAV, Navy TENCAP

TCS DEVELOPMENTAL TESTING FLIGHT OPERATIONS SUPPORT

Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Naval Air Systems Command

OBJECTIVE: Provide predator UAV flight support for Prairie Dog II. CIRPAS provided 30 flight hours during a three-week mission window.

SUMMARY: TCS provides joint war-fighters with interoperable and scalable command, control, communications, and data dissemination systems for the family of present and future Medium Altitude Endurance (MAE) and tactical Unmanned Aerial Vehicles (UAVs). TCS will also receive and disseminate data for the High Altitude Endurance (HAE) UAVs. The TCS program is managed by PMA-263. Fundamental to TCS definition is a series of demonstrations and tests to gain war-fighter recognition and feedback on user needs. CIRPAS has been asked to support the developmental testing (DT) of Engineering Development Unit #2 (EDU2). EDU2 is the Raytheon-manufactured TCS slated for delivery to JTFCOM. DT will include Level 5 flight activity.

DoD KEY TECHNOLOGY AREAS: Other (UAV Technology)

KEYWORDS: UAV, Predator, TCS

FORMATION AND PERPETUATION OF RIFTS AND GRADIENTS IN OPTICAL AND MICROPHYSICAL PROPERTIES OF MARITIME STRATUS

Haflidi Jonsson, Research Assistant Professor
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: National Science Foundation

OBJECTIVE: Measurements of the physical characteristics of in cloud-free areas (rifts) embedded in stratus and stratocumulus.

SUMMARY: A rift came into the range of the CIRPAS Twin Otter during the DECS experiment in 1999, and was explored in detail. Analysis of the data obtained has been performed by Neil Smith in the Meteorology Department, who completed a Master's thesis on the topic, and by a graduate student at the University of Miami, who is still working on a project. The last year's funding has been extended to obtain further measurements should an opportunity present itself during the CARMA and DECS-II experiments scheduled to take place in Marina, CA, in August-October 2002.

DoD KEY TECHNOLOGY AREAS: Other (Geosciences)

KEYWORDS: Stratus, Stratocumulus, Rifts, Visibility Marine Boundary Layer

INTEGRATION OF AEROSOL AND WIND LIDAR ONTO CIRPAS' TWIN OTTER

Haflidi Jonsson, Research Assistant Professor
Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: National Oceanic and Atmospheric Agency

OBJECTIVE: Installation and flight-testing a new aerosol and wind lidar.

SUMMARY: Funding from ONR and the IPO has enabled ~ 15 hours of airborne Doppler Wind Lidar (DWL) operations to conduct experiments related to lidar surface returns from water surfaces and to explore several issues related to the cal/val of any future space-based DWL. The first series of flights (February 9 - 15) was spent in the vicinity of Monterey, CA. Another series of flights took place near Boulder, Colorado (March 12 -15) where the airborne DWL was compared with a ground based lidar, a microwave sounder, and measurements from an instrumented tower. The lidar's scanner was mounted in the door of the CIRPAS Twin Otter and permitted scanning up, down, and sideways in a variety of patterns. While a 2 micron coherent system was used in these experiments, some of the questions being addressed apply generally to direct detection as well. Some "quicklook" data and a description of the experiments are provided at the TODWL (Twin Otter Doppler Wind Lidar) web site www.swa.com/TODWL. The lidar is being transferred to a trailer for use by the PI between airborne experiments. The intent is to reinstall the lidar on the Twin Otter for future participation in field campaigns, special underflights of other airborne instruments, and DWL cal/val activities.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Marine Meteorology)

KEYWORDS: Lidar, NPOESS, Winds, Aerosol

NAVAL POSTGRADUATE SCHOOL/CIRPAS SUPPORT OF OFFICE OF NAVAL RESEARCH AIRBORNE RESEARCH

Haflidi Jonsson, Research Assistant Professor
Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research and National Oceanic and Atmospheric Agency

OBJECTIVE: The projects were carried out using the CIRPAS Twin Otter, UV-18A and various scientific instruments from CIRPAS' airborne and calibration suites. Operations were supported by CIRPAS' scientific and flight operations personnel. CIRPAS provided GPS, and meteorological data to the projects, and also measurements from other facility instruments as requested for each project. CIRPAS provided a data system consisting of several computers, networked and synchronized to GPS time. The data system not only serviced the facility equipment, but also the special research instruments maintained and operated by the PIs themselves, their Co-PIs, and students.

SUMMARY: CIRPAS supported the airborne research objectives of the Office of Naval Research (ONR). Four individual research projects were supported independently using CIRPAS personnel, instrumentation, and aircraft. These projects were: 1) ACE-ASIA – A study of Asian dust transported off the continent. PI was Professor John Seinfeld of California Institute of Technology. 2) HALO – A study of water vapor in vicinities of clouds and its effects on the Earth's radiation budget. PI was Professor John Seinfeld of California Institute of Technology. 3) CLOUD – A study of entrainment into stratus and stratocumulus clouds. PI was Professor Bruce Albrecht of the University of Miami. 4) RED – A multifaceted study of scintillation effects on light and signal transmission in the marine boundary layer, aerosol and cloud chemistry and micro-physics, and turbulence. A science team consisting of Mr. Ken Anderson and Dr. Jeff

Reid from SPAWAR, San Diego, Dr. Dean Hegg of University of Washington, Professor Carl Friehe of University of California, Irvine, and Dr. Haf Jonsson, NPS directed the mission and defined individual flight objectives.

DoD KEY TECHNOLOGY AREAS: Other (Geosciences)

KEYWORDS: Meteorology, Aerosol, Optical depth, Visibility

THE OPTICAL PROPERTIES OF THE MARITIME AEROSOL AND THEIR CORRELATION TO THE ELECTRICAL CONDUCTIVITY IN THE MARINE BOUNDARY LAYER

Haflidi Jonsson, Research Assistant Professor
Robert Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research

OBJECTIVE: Aircraft measurements of aerosol/optical properties and size spectra, along with simultaneous measurements of the electrical conductivity of the air were used to investigate the feasibility waves in the marine boundary layer.

SUMMARY: Measurements of size distributions, extinction and conductivity were obtained during the RED experiment in Hawaii in the summer of 2001. Analyses of the measurements has yet to be performed.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications

KEYWORDS: Conductivity

CENTER FOR INTERDISCIPLINARY REMOTELY PILOTED AIRCRAFT STUDIES (CIRPAS)

2001
Faculty Publications and Presentations

JOURNAL ARTICLES

Baumgardner, D., H. Jonsson, W. Dawson, D. O'Connor and R. Newton, The cloud, aerosol and precipitation spectrometer (CAPS): A new instrument for cloud investigations, *Atmospheric Research*, Vol. 59-60, pp. 251-264, 2001.

Hegg, D.A., S. Gao and H. Jonsson, Measurements of selected dicarboxylic acids in marine cloud water, *Atmospheric Research*, Vol. 62, pp. 1-10, 2001.

Hegg, D.A., D.S. Covert, K. Crahan and H Jonsson, The dependence of aerosol light-scattering on RH over the Pacific Ocean, *Geophysical Research Letters*, 2001.

Reid, J.S., D.L. Westphal, J.M. Livingston, D.L. Savoie, H.B. Maring, H.H. Jonsson, D.P. Eleuterio and J.E. Kinney, Dust vertical distribution in the Caribbean during the Puerto Rico dust experiment, *Geophysical Research Letters*, 2001.

Reid, J.S., H.H. Jonsson, M.H. Smith and A. Smirnov, Evolution of the vertical profile and flux of large sea-salt particles in the coastal zone, *Journal of Geophysical Research*, Vol. 106, pp. 12,039-12,053, 2001.

SCHOOL OF
AVIATION SAFETY

CAPT KENNETH P. NEUBAUER, USN
DIRECTOR

SCHOOL OF AVIATION SAFETY

OVERVIEW:

The School of Aviation Safety's mission is to educate aviation officers at all levels to identify and eliminate hazards, to manage safety information, to investigate and report mishaps, and to develop and administer command safety programs. The School of Aviation Safety conducts safety related research and provides assistance in support of the Naval Aviation Safety Program. The combined teaching, research, and service is dedicated to enhancing combat readiness through preservation of assets, both human and material.

CURRICULA SERVED:

- Aviation Safety Officer (ASO) Course: A 21-day course designed to prepare Aviation Safety Officers to assist commanders and commanding officers in administering unit safety and mishap prevention programs.
- Aviation Safety Command (ASC) Course: A six-day course designed to indoctrinate aviation squadron commanding officers, officers screened for command, and major aviation staff officers in the policies, philosophy, and techniques of an effective command safety program.

RESEARCH THRUSTS:

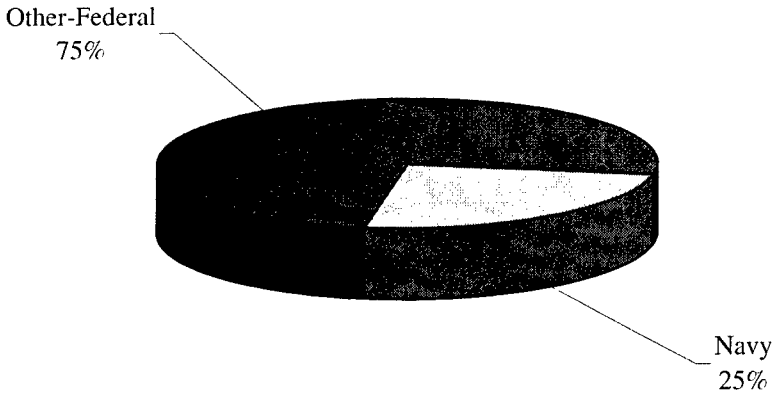
- Human Factors of Air Safety: An area of research dealing with the underlying causes of human error in aviation mishaps, including individual, team and organizational factors that may contribute to the chain of events leading to an aircraft mishap. Researchers at the School of Aviation Safety have developed a Human Factors Checklist that defines specific human performance factors commonly associated with aircraft mishaps.

- Command Climate Assessment Surveys: The School of Aviation Safety has been a leader in the development and application of web-based surveys used to assess Command Climate. Two survey applications have been developed, and are in use today by U.S. Navy and U.S. Marine Corps units. The Command Safety Assessment (CSA) survey system is used to assess command climate, the perceived effectiveness of a commands safety program, and other factors related to the safety of flight operations. The Maintenance Climate Assessment Survey (MCAS) was developed to address similar command issues in the maintenance community. MCAS also measures command climate and other factors, but with respect to maintenance operations. CSA/MCAS are designed specifically for the aviation application. A derivative of the on-line MCAS process focusing specifically on Naval Aviation Depot (NADEP) issues has also been developed and implemented. Recently, the School of Aviation researchers have begun to develop and apply the same command climate assessment methods to USMC Ground Forces, and have begun migrating these survey methods in support of the NASA manned space program.

- Organizational Risk Factors: An area of research dealing with the potential influence of leadership, organizational structure, safety climate, and safety culture, on mishap causation. Researchers at the School of Aviation Safety are working in collaboration with social scientists from Haas Business School, UC Berkeley, Stanford University, Carnegie-Mellon, University of Arizona, and NASA-Ames Research Center to develop and validate Organizational Risk Models. This research is closely allied to the ongoing development and application of the U.S. Navy and U.S. Marine Corps Command Climate Assessment Surveys.

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 School of Aviation Safety is provided below:



Size of Program: $232K

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ORGANIZATIONAL SAFETY RISK ASSESSMENT SYSTEM

Anthony P. Ciavarelli, Professor
School of Aviation Safety
Sponsor: U.S. Marine Corps Ground Forces

OBJECTIVE: The objective of this study is to develop, and validate, a methodology for assessing the effectiveness of organizations in the management of risks associated with hazardous operations.

SUMMARY: A prototype *Aviation Command Safety Assessment* questionnaire was developed and administered to U.S. Navy and Marine Corps units in August 1996. The questionnaire was designed to measure the extent to which a particular naval squadron met criteria of a so-called *High Reliability Organization.* Construction of the questionnaire was based primarily on the work of Karlene Roberts (1990), from the Haas Business School, UC Berkeley, and her colleague Carolyn Libuser (1994) from the University of California at Los Angeles. It was Roberts who coined the term high-reliability organization (HRO). Roberts and Libuser studied organizations in terms of their ability to effectively manage risks associated with possible accidents and material or financial losses. Results of the 1996 survey were presented to the Navy's ongoing human factors Quality Management Board (QMB) study of naval mishaps. Findings from the study were used by the U.S. Navy to initiate a series of planned safety interventions, including a provision for continuous measurement of organizational safety effectiveness. Over the past few years, the survey questionnaire has been refined based upon statistical validation data, and an Internet-based version was developed. The questionnaire is now available to U.S. Navy and Marine Corps units via a secure Internet Web site. (http://www.safetyclimatesurveys.org/index1.asp). The web-based survey provides aviation commanders with a means to administer the survey and to receive immediate feedback concerning key issues related to command climate, safety culture, workload, resource availability, estimated success of certain safety intervention programs, and other factors related to safely managing fleet flying operations. A key goal of the survey method, and Internet technology application, is to identify and correct any latent organizational conditions that may lead to increased accident risk. In April 2001 Dr. Ciavarelli initiated an additional application of this methodology to U.S. Marine Corps Ground Forces, with research and development funding from the HQ USMC. The new system will be fully developed by October 2002. The prototype of the U.S. Marine Corps Web site is viewable at: https://miras.universal-net.com/usmc/login.html. Research plans include migration of this very successful program to the civilian sector. For example, Dr. Ciavarelli participates with a Stanford University/VA Hospital research team headed by Stanford University professor (Dr. David Gaba). The Stanford University research team uses an adapted version of the survey to examine organizational culture in medical delivery agencies. Dr. Ciavarelli is also developing an application of the web-based survey for civilian flight schools, as a consultant to Embry-Riddle Aeronautical University.

PUBLICATIONS:

Gaba, D., Singer, S., Sinaiko, A. and Ciavarelli, A.P., "Safety Culture Differences between Hospital Personnel and Naval Aviators," *Human Factors*, 2002, in press.

Ciavarelli, A.P., Figlock, R., Sengupta, K. and Roberts, K.H., "Assessing Organizational Risk Using Survey Questionnaire Methods," *Proceedings, Eleventh Biennial International Symposium on Aviation Psychology*, Ohio State University, Columbus, OH, 5-8 March 2001.

THESES DIRECTED:

Flowers, T.R. and Dowler, DM., "Development of an Expert System and Software Agent for the Aviation Command Safety Assessment System," Masters Thesis, Naval Postgraduate School, March 2000.

Williams, T.G., "Usability of the Aviation Command Safety Assessment Web-Based Questionnaire," Masters Thesis, Naval Postgraduate School, March 1999.

Held, J.S. and Mingo, F.J., "Automating the Aviation Command Safety Assessment Survey as an Enterprise Information System," Masters Thesis, Naval Postgraduate School, March 1999.

DoD KEY TECHNOLOGY AREAS: Other (Aviation Safety)

KEYWORDS: Organizational Effectiveness, Safety Culture, Risk Management, Survey Method, System Safety, Human Factors, Human Factors Engineering, Engineering Psychology, Human Performance, Human Error

ORGANIZATIONAL RISK MODEL DEVELOPMENT

Anthony P. Ciavarelli, Professor
School of Aviation Safety
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: The objective of this study is to develop, and validate, an organizational risk assessment model for use by the National Aeronautics and Space Administration (NASA).

SUMMARY: A program of research has been initiated to develop and validate an organizational risk assessment model, for use in the NASA space exploration program. Dr. Ciavarelli is working with a research team consisting of research psychologists at the NASA-Ames Research Center, Carnegie-Mellon University, and the University of Arizona. Dr. Ciavarelli will be drawing from his existing work related to organizational factors in aviation accidents (Ciavarelli and Figlock, 2001; 1997), the works of Roberts (1990) and Libuser (1994), Gaba, Singer, Sinaiko, and Ciavarelli, 2002). In addition he is conducting an extensive revile of the extant literature on High-Reliability organizational theory, and safety culture. A preliminary organizational risk assessment model will be outlined, based upon this literature review, and will include candidate measures and metrics for assessing the potential contribution of organizational factors to a variety of risk areas, such as accident risk, mission failure, program slippage, financial loss, and other loss potentials. Dr. Ciavarelli will lead the construction of a web-based survey technology, using an adapted version of the U.S. Marine Corps web-survey system. The web-survey technology will provide a means to rapidly construct questionnaire surveys, and to receive immediate feedback of results, and will enable normative data comparisons among survey samples and populations. The system may be used by the NASA research team as a means for exchanging views and for reaching a decision consensus during risk model development. Later, the resulting online web-survey method may serve as one means of providing a risk-decision support system for mitigating design, development, and operational risk for the International Space Station. The final organizational risk assessment model will result from a team effort that requires a final integration of related collaborative efforts at NASA, NPS, and other academic institutions. Once developed and validated, the resulting organizational risk assessment model will be applicable to both civilian and military agencies. Outputs from this study are expected to greatly enhance the ongoing efforts to measure and assess operational risks in U.S. Naval Aviation and U.S. Marine Corps ground forces.

PUBLICATIONS:

Gaba, D., Singer, S., Sinaiko, A. and Ciavarelli, A.P., "Safety Culture Differences between Hospital Personnel and Naval Aviators," *Human Factors*, 2002, in press.

Ciavarelli, A.P., Figlock, R., Sengupta, K. and Roberts, K.H., "Assessing Organizational Risk Using Survey Questionnaire Methods," *Proceedings, Eleventh Biennial International Symposium on Aviation Psychology*, Ohio State University, Columbus, OH, 5-8 March 2001.

Ciavarelli, A.P., "Human Factors Checklist: A tool for Accident and Incident Investigation," *Flight Safety Digest*, Flight Safety Foundation, Washington D.C., February 2001.

Ciavarelli, A.P., "Assessing the Quality of Instruction: Integrating Instructional Quality and Web Usability Assessments," *Measuring Up: Assessment Issues for Teachers, Counselors, and Administrators*, ERIC Clearing House for Teaching and Research, Washington D.C., 2002, in press.

Ciavarelli, A.P. and Figlock, R., "Organizational Factors in Naval Aviation Accidents," The 1997 International Symposium on Aviation Psychology, Columbus, OH, 1997.

PRESENTATIONS:

Ciavarelli, A.P., Figlock, R., Sengupta, K. and Roberts, K.H., "Assessing Organizational Risk Using Survey Questionnaire Methods," Eleventh Biennial International Symposium on Aviation Psychology, Ohio State University, Columbus, OH, 5-8 March 2001.

Ciavarelli, A.P., "Organizational Factors in Aviation Accidents," Human and Organizational Risk Management Workshop, NASA/Ames Research Center, Moffett Field, CA, April 2001.

Ciavarelli, A.P., "Organizational Factors and Flight Crew Risk Behavior," Fourthy Fifth Annual Meeting of the Human Factors and Ergonomics Society, Minneapolis, MN, October 2001.

Ciavarelli, A.P., "The Human Factors of Air Safety," NASA Human Error Modeling Workshop, NASA/Ames Research Center, Moffett Field, CA, June 2000.

DoD KEY TECHNOLOGY AREAS: Other (Aviation Safety)

KEYWORDS: Organizational Behavior Models, Risk Assessment, Safety Culture, Survey Methods, System Safety, Human Factors, Human Factors Engineering, Engineering Psychology, Human Performance, Human Error

MAINTENANCE ERROR RISK ASSESSMENT AND STRATEGIC INTERVENTION

Robert C. Figlock, Assistant Professor
John K. Schmidt, Assistant Professor
School of Aviation Safety
Sponsor: NASA Ames Research Center

OBJECTIVE: Develop a process to recognize human error and its sources in aviation maintenance related incidents. Specifically, the goal is to identify human factors issues in maintenance related mishaps, flight mishaps, flight related mishaps, aircraft ground mishaps, identified aviation hazards, and personal injuries to determine their characteristics, discern any significant patterns and trends, prioritize target areas for intervention, and design appropriate risk management intervention strategies. Results are applicable to both military and commercial aviation maintenance operations.

SUMMARY: Current methods used in commercial airlines to investigate maintainer error are shown to be typically restricted to reactive analysis of error causation. These methods focus on proximate causes and immediate circumstances surrounding an adverse occurrence. The first task of this on-going effort was to develop, implement, and evaluate a Maintenance Error Information Management System (MEIMS) to catalog, classify, and analyze maintenance related incidents using the Navy's Human Factors Analysis and Classification System-Maintenance Extension (HFACS—ME) taxonomy as its framework. MEIMS provides for the examination of the latent conditions leading to errors. A second task of this project was to design a standard process to identify, measure, and assess maintenance errors. A web-based Maintenance Climate Assessment Survey (MCAS) process was developed focusing on commercial aviation maintenance activities. Both the MEIMS and MCAS systems that were developed have military aviation maintenance applicability.

PUBLICATIONS:

Figlock, R. and Schmidt, J., "Development of a Web-Based Maintenance Climate Assessment Survey," *Proceedings, 2001 Aerospace Congress, Aerospace Congress and Exhibition*, Seattle, WA, 10-14 September 2001.

Schmidt, J. and Figlock, R., "Maintenance Climate Assessment: Survey Development and Preliminary Results," *Proceedings, Eleventh Biennial International Symposium on Aviation Psychology*, Ohio State University, Columbus, OH, 5-8 March 2001.

PRESENTATIONS:

Figlock, R., "Command Safety Climate Assessment Surveys," Aviation Education 2020 Conference, Naval Postgraduate School, Monterey, CA, 29-30 January 2001.

Figlock, R. and Schmidt, J., "Maintenance Climate Assessment: Survey Development and Preliminary Results," Eleventh Biennial International Symposium on Aviation Psychology, Ohio State University, Columbus, OH, 5-8 March 2001.

Figlock, R., "Development of a Web Based Maintenance Climate Assessment Survey," 2001 SAE Aerospace Congress and Exhibition, Seattle, WA, 10-14 September 2001.

Figlock, R. and Ford, J., "Command Safety Assessment and Maintenance Climate Assessment Survey Demonstration," Civil Aviation Safety Team Conference, Alexandria, VA, 15 October 2001.

Figlock, R. and Ford, J., "Command Safety Assessment and Maintenance Climate Assessment Survey Demonstration," Headquarters Marine Corps Safety Division Conference, Washington, D.C., 16 October 2001.

THESES DIRECTED:

Boex, A., "Web-Based Information Management System Development for the Investigation, Reporting and Analysis of Human Error in Naval Aviation Maintenance," Masters Thesis, Naval Postgraduate School, September 2001.

Nelson, D., "Information Management System Development for the Investigation, Reporting, and Analysis of Human Error in Naval Aviation Maintenance," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Other (Aviation Safety)

KEYWORDS: Human Error, Maintenance Error, Flight Mishaps, Aviation Mishaps, Aviation Accidents, Flight Mishap Investigation, Aviation Mishap Investigation, Aviation Accident Investigation, Flight Mishap Prevention, Aviation Mishap Prevention, Aviation Accident Prevention, Design for Maintainability, System Safety, Design for Maintainability, Human Factors, Human Factors Engineering, Engineering Psychology, Human Performance, Human Error

RELIABILITY BUSINESS PROCESS REENGINEERING

Robert C. Figlock, Assistant Professor
John K. Schmidt, Assistant Professor
School of Aviation Safety
Sponsor: Naval Aviation Depot - Cherry Point

OBJECTIVE: Develop a process to recognize human error and its sources in aviation maintenance related incidents. Specifically, the goal is to identify human factors issues in maintenance related mishaps and injuries to determine their characteristics, discern any significant patterns and trends, prioritize target areas for intervention, and design appropriate risk management intervention strategies. This project's primary focus was on Naval Aviation Depot (NADEP) issues and concerns.

SUMMARY: A three-prong strategy was implemented for this project. First, a Maintenance Error Information Management System (MEIMS) was developed to catalog, classify, and analyze maintenance related incidents using the Naval Safety Center's Human Factors Analysis and Classification System—Maintenance Extension (HFACS—ME) taxonomy as its framework. Results were used to develop tailored case studies and training materials for use in maintenance error presentations and human factors intervention workshops. The presentations/workshops were provided to NADEP Cherry Point managers.

Second, a web-based Maintenance Climate Assessment Survey (MCAS) process was designed and developed focusing on depot-level maintenance activities. The on-line survey was then implemented at the NADEP (see: www.safetyclimatesurveys.org/nadep/index1.asp). Third, a web-based, depot-level, Maintenance Resource Management (MRM) module was developed to enhance NADEP maintenance personnel's safety awareness and skills. The MRM module will be part of the Navy's on-line Safe Maintenance in Aviation, Research, and Training (SMART) Center.

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DoD KEY TECHNOLOGY AREAS: Other (Aviation Safety)

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SCHOOL OF AVIATION SAFETY

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