DRAFT
Summary of Research
2008

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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President                         Provost

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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, the Cebrowski Institute (formerly the Institute for Information Innovation and Superiority, I2SI), the Wayne E. Meyer Institute of Systems Engineering (formerly the Institute for Defense Systems Engineering and Analysis, IDSEA), the MOVES Institute (Modeling, Virtual Environments, and Simulation), the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS), the Center for Defense Technology and Education for the Military Services (CDTEMS), the National Security Institute, the Center for Asymmetric Warfare, and the Center for Contemporary Conflict.
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 2008. 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.edu (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://www.nps.edu/Research/index.html.

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://www.nps.edu/Research/Publications/SummaryRes.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/Department of Defense (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 policy-makers throughout the Navy, the DoD, other government agencies, and 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 2008, the level of research effort overall at the Naval Postgraduate School was XXX faculty work years and exceeded $XXX 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 FY2008, over XXX% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2008 is provided in Figure 1.
The Chief of Naval Operations 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 FY2008 is provided in Figure 2.

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.

Daniel C. Boger
Dean of Research

December 2009
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SCHOOL OF INTERNATIONAL GRADUATE STUDIES

PAUL STOCKTON
DEAN
DEFENSE RESOURCES
MANAGEMENT INSTITUTE

CHARLES J. LACIVITA
EXECUTIVE DIRECTOR
OVERVIEW:

Established in 1965, the Defense Resources Management Institute (DRMI) conducts professional education programs in resources management for senior military officers from all services and senior civilian officials from the United States and allied nations. The goal of the Institute’s programs is to improve decision-making skills related to the allocation and use of scarce resources in modern defense organizations. The DRMI programs are sponsored by the Office of the Secretary of Defense and use NPS faculty to teach its programs, which are conducted at NPS and other locations worldwide. Since 1965, over 14,000 U.S. and 16,000 international officials from 162 countries have participated in DRMI programs.

MISSION:

The DRMI research program is sponsored by the Office of the Secretary of Defense and is designed to support the multidisciplinary nature of the curriculum. The program exceeded $XXXXK in 2008.

RESIDENT COURSES OFFERED:

- Defense-Resources Management
- International Defense-Resources Management
- Senior International Defense-Resources Management
- Multiple-Criteria Decision Making
- Budget Preparation, Execution, and Accountability
- Financial Integrity, Accountability, and Transparency
- Streamlining Government through Outsourcing, Privatization, and Public-Private Partnerships
- Base Realignment and Closure and Economic Redevelopment

FACULTY EXPERTISE:

DRMI’s multidisciplinary faculty is drawn from the fields of management, economics, operations research, and systems engineering. The faculty is composed of both civilians and U.S. military officers representing all services.

RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. The School of International Graduate Studies’ program exceeded $22.8M in 2008.
Size of Program: $22.8M
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</table>
OBJECTIVE: To enhance the joint understanding of common analytical techniques that can be employed in the public and private sectors in support of multi-criteria decision-making. The focus will be on the latest research in methods of multi-criteria decision-making, including topics in economics, cost analysis, and uncertainty. A second workshop was held in Seattle, Washington, from 14-17 January 2008.
DEFENSE RESOURCES
MANAGEMENT INSTITUTE

2008
Faculty Publications
and Presentations
DEPARTMENT OF NATIONAL SECURITY AFFAIRS

HAROLD A. TRINKUNAS
CHAIR
OVERVIEW:

The Naval Postgraduate School’s (NPS) Department of National Security Affairs (NSA) specializes in the study of international relations, security policy, and regional studies. NSA is unique because it brings together outstanding faculty, students from the Army, Air Force, Navy, Marines, National Guard, and various civilian agencies, and scores of international officers from dozens of countries for the sole purpose of preparing tomorrow’s military and civilian leaders for emerging security challenges.

The faculty is made up of approximately fifty professors and instructors. Most are full-time faculty at NPS, and approximately 29 are tenured or tenure-track. Every member of the faculty is a specialist in an aspect of security studies or in the politics and culture of a specific region. The faculty members are drawn from the top Ph.D.-granting institutions in history, political science, and economics. They are deeply involved in cutting-edge academic research and publication, enhancing their ability to provide superior, graduate-level education in support of U.S. national security interests. The study of security studies at NPS has been listed among the top ten universities in the 2006-2007 Faculty Scholarly Productivity (FSP) Index in the International Affairs and Development category. The faculty pride themselves on being responsive to the evolving needs of research and curricula sponsors, which creates a dynamic and exciting environment for students. Unlike other graduate programs, faculty, not research assistants, actually teach all classes.

The NSA Department focuses on Master’s-level graduate education in regional and international security studies, offering a wide range of interdisciplinary, in-residence, degree programs in these fields. NSA Master’s programs require between 12 and 18 months of in-residence study to complete. Most require completion of a Master’s thesis or supplementary language training at the Defense Language Institute, also located in Monterey. NSA also offers a Ph.D. in Security Studies, which requires a minimum of two years of in-residence work beyond completion of a related Master’s degree.

The Department also supports U.S. national security policy by providing a variety of mobile education formats and locally hosted short-courses and by pushing research findings directly to the policy-making and implementing communities via the Center for Contemporary Conflict.

NSA also maintains close relations with three affiliated centers: the Center for Civil-Military Relations, the Center for Stabilization and Reconstruction Studies, and the Center for Homeland Defense and Security. Each of these contributes at the intersection of the academic and policy spheres in their respective substantive areas, and NSA faculty frequently work within them according to their areas of expertise. All of these institutions are components of the Naval Postgraduate School’s School of International Graduate Studies, which also coordinates a range of regional studies programs beyond NPS.

CURRICULA SERVED:

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

DEGREES GRANTED:

- Master of Arts in National Security Affairs
- Master of Arts in Security Studies
- Doctor of Philosophy in Security Studies
RESEARCH THRUSTS:

- Strategic Studies
- Comparative Politics
- Terrorism, Ethnic Conflict, and Sub-State Actors in Security 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
- Center for Civil-Military Relations
- Center for Stabilization Reconstruction and Studies
- Center for Homeland Defense and Security

RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. The School of International Graduate Studies’ program exceeded $22.8M in 2008. A profile of the sponsored program for the School of International Graduate Studies is provided below:

Size of Program: $22.8M
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<tr>
<td>Yost, David S.</td>
<td>Professor</td>
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</table>
ATTRIBUTING THE USE OF BIOLOGICAL WEAPONS AGENTS
Anne L. Clunan, Assistant Professor
Peter Lavoy, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To assess the challenges that policy-makers and military commanders face in correctly identifying and attributing responsibility for the use of biological warfare agents (BW). Looking at past cases from World War II to the present, the project examines the difficulties involved in knowing when state and non-state actors have employed BW agents and assessing how governments fared in identifying BW use, managing the information campaign of attribution, and responding to allegations of attacks.

SUMMARY: In 2008, Professor Clunan led and completed the final editing and production of an anthology based on a conference that brought together governmental and non-governmental experts in London from 11-13 July 2006. The edited volume, published by Stanford University Press in 2008, collected expert analysis of confirmed, suspected, and fabricated BW agent releases, as well as an assessment of lessons that can be drawn and implemented by current-day policy-makers for managing the problems of BW identification, characterization, and attribution. Professor Clunan conducted research, wrote two chapters, and co-authored a third chapter for the edited volume.

BOOK:
Clunan, A.L., Lavoy, P.R., and Martin, S.B. (Eds.), Terrorism, War, or Disease? Unraveling the Use of Biological Weapons, Stanford University Press, August 2008.

CONTRIBUTIONS TO BOOKS:


KEYWORDS: Biological Weapons, Biological Warfare, Bioterrorism, Biosecurity, Disease, Attribution, Information-Sharing, Proliferation, Nonproliferation, Terrorism, Deterrence, WMD, Weapons of Mass Destruction, Anthrax, Anthrax Attacks, Plague, Germ Warfare, Yellow Rain, Thrips, Japan, India, Korea, Cuba, China, United States, United Kingdom, Biological and Toxin Weapons Convention, Multilateral Treaties
CONTESTED SPACES: THREATS AND RESPONSES
Anne L. Clunan, Assistant Professor
Department of National Security Affairs
Michael E. Freeman, Assistant Professor
Department of Defense Analysis
Sponsor: Center for Stabilization and Reconstruction Studies, Naval Postgraduate School

OBJECTIVE: To assess the challenges that policy-makers face and their responses when confronted with areas that are conventionally labeled as “ungoverned spaces,” or more accurately as “zones of competing governance” or “contested spaces.” The project will consider how ideologies, such as Salafism and liberalism, have flourished in virtual and physical realms and contributed to the rise of contested spaces. These areas are frequently found in failed or failing states, but also, importantly, in strong states. While most studies of this phenomenon have tended to view it through a geographic lens, the principal investigators in this research propose to broaden the conception of contested spaces beyond the simply geographic realm to include the ideational and virtual realms. The project will focus on the threats posed by radical, ideological movements that thrive in such spaces and on the responses of states in the broader international context of state sovereignty and global liberalization. The end-product will be a comprehensive dataset mapping the Salafist networks of finances, institutions, and individuals, and a book-length project outline.

SUMMARY: Professor Clunan supervised research on the responses of states to contested spaces arising in the area of energy and security and delivered a presentation on the effects of contested spaces and globalization for WMD proliferation.

PRESENTATIONS:


KEYWORDS: Ungoverned Spaces, Sovereignty, Globalization, Fragile States, Failed States, Failing States, Liberalization, Liberalism, Ideology, Threats, Threat Definition

THE DEFINITION OF NATIONAL SECURITY INTERESTS AND INSTITUTIONAL CHANGE
Anne L. Clunan, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School, Research Initiation Program

OBJECTIVE: To investigate how and why post-Soviet Russia defines its national security interests regarding strategic arms control and European security in times of dramatic change.

SUMMARY: Professor Clunan completed revision to the book manuscript, and it was accepted for publication with Johns Hopkins University Press in April 2008.

PRESENTATION:

BOOK:

KEYWORDS: Russia, Security Policy, Foreign Policy, National Interests, NATO, Europe, Former Soviet Union, Nuclear Arms Control, Missile Defenses, Social Psychology, Identity, International Relations Theory, Ingroups, Outgroups

UNGOVERNED SPACES
Anne L. Clunan, Assistant Professor
Harold A. Trinkunas, Associate Professor
Department of National Security Affairs
Sponsor: Center for Civil Military Relations, Naval Postgraduate School

OBJECTIVE: “Ungoverned spaces” are increasingly cited as a key threat to the U.S. government and its interests throughout the world. This project proposes to analyze the concept of ungoverned spaces and determine whether they really are ungoverned and whether they constitute threats to states. Governance exists in areas frequently claimed as ungoverned, such as feral cities, failed states, offshore financial markets, and tribal areas (such as the Afghan-Pakistan border). The notion of ungoverned spaces is potentially even more broadly applicable to areas within otherwise functioning states, including the United States, where authority and jurisdiction are exercised by non-state actors. This ongoing project brings together international scholars with a broad interest in the problem of “ungoverned spaces,” including work focused on megacities, organized crime, transnational gangs, “home-grown” terrorist cells, money laundering, weapons of mass destruction (WMD) proliferation networks, the privatization of security services, and the rise of Internet social movements. The principal participants continue to contribute to an edited volume on the subject of ungoverned spaces.

SUMMARY: Professors Clunan and Trinkunas organized a major, ongoing research project in 2007 regarding the threats posed by ungoverned spaces, including a conference held at the Naval Postgraduate School from 2-3 August 2007. The conference was co-sponsored by the Center for Civil Military Relations at the Naval Postgraduate School and the Defense Threat Reduction Agency/Advanced Systems and Concepts Office. In 2008, Professors Clunan and Trinkunas edited and commented on all participants’ papers and submitted the volume for review by Stanford University Press.

PRESENTATION:


UNGOVERNED SPACES
Anne L. Clunan, Assistant Professor
Jessica Piombo, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To assess the command and control challenges that civilian and military planners face when dealing with “ungoverned spaces” and the weapons of mass destruction (WMD) proliferation and terrorism threats that arise from them. Ungoverned spaces are increasingly cited as a key threat to the U.S.
NATIONAL SECURITY AFFAIRS

government and its interests throughout the world. Often these spaces are seen as synonymous with failed states, or states that are unable to effectively exercise sovereignty. A key goal of current U.S. defense strategy is to improve “effective sovereignty” in such areas in order to deny sanctuary to WMD proliferators, terrorists, arms- and narco-traffickers, and gangsters. This project will expand the understanding of ungoverned spaces beyond the commonplace notion of “failed,” “failing,” or “fragile” states to address spaces within otherwise functioning states that may harbor WMD proliferation networks or facilitate WMD terrorism. It will investigate which ungoverned spaces are priority threats to the United States and its allies. It will conclude with an analysis of early warning indicators and policy-makers’ and military planners’ attempts to manage the WMD proliferation and terrorism threats arising from ungoverned spaces in Africa, Asia, Eurasia, and the Americas.

SUMMARY: In this ongoing project, Professor Clunan commissioned a series of research papers from subject-matter experts, including Professor Piombo, to assess cases of ungoverned spaces around the world; examine early warning indicators of ungovernability, WMD proliferation, and WMD terrorism networks; and analyze how military and civilian governmental agencies have responded in the past to WMD threats arising from ungoverned spaces. These papers were delivered at the Conference on Ungoverned Spaces, which was co-organized by Professors Clunan and Trinkunas and held at the Naval Postgraduate School from 2-3 August 2007. Professor Clunan presented findings for policy-makers and military planners in 2008.

PRESENTATION:


KEYWORDS: Ungoverned Spaces, Sovereignty, Globalization, Fragile States, Failed States, Failing States, Proliferation, WMD, Weapons of Mass Destruction, Threats, Threat Definition

PREVENTING TERRORIST ATTACKS: INTELLIGENCE WARNING AND POLICY RESPONSE

Erik J. Dahl, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: To contribute to the study of intelligence by improving our understanding of the factors that contribute to intelligence failure and success; and to contribute to the the field of terrorism studies by focusing on the under-studied area of lessons that can be learned from failed terrorist attacks.

SUMMARY: This work is continuing. The principal investigator intends to draft a book manuscript, develop and analyze a new database of unsuccessful terrorist plots and attacks, and write a journal article based on that database. During the time of this report, the principal investigator has begun all three of these projects and given a presentation based on this research.

PRESENTATION:


CONTRIBUTION TO BOOK:

THE DEVELOPMENT OF TALIBAN COUNTER-NARRATIVES
Thomas H. Johnson, Research Professor
Department of National Security Affairs and Program for Culture and Conflict Studies
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: The Program for Culture and Conflict Studies (CCS) has been tasked by the Joint Improvised Explosive Device Defeat Organization (JIEDDO) to conduct research on Pashtun culture and narratives relative to the use of improvised explosive devices (IED). In order to effectively counteract IEDs in Afghanistan, it is essential to understand their human masters and the narratives that drive them and develop successful counter-narrative techniques.

SUMMARY: This study analyzed IED narratives in Afghanistan from a variety of sources, including Taliban press releases and night letters (shabnamah), local media, and when possible, the messages and accounts of the bombers themselves. While sacrifice and martyrdom are virtues among Afghan jihadi narratives, deliberate suicide (which accounts for approximately 10 percent of IED attacks in Afghanistan) is culturally anathema. Traditionally, anonymous attacks (such as roadside bombs) were similarly shunned. This project identified the insurgent discourses making IEDs culturally acceptable, analyzed them, and disassembled them. If the tactics of IEDs and suicide can be effectively demonstrated as being culturally unacceptable, support for these tactics among the rural population can be substantially reduced.

FIELD RESEARCH:

Afghanistan Field Research. From August 1–September 14, Professor Johnson engaged senior U.S. military commanders, ODA teams, IO and POTF personnel, tribal elders, local Afghan politicians, subject matter experts, and a variety of individuals and groups in order to gather data and assess the situation in Afghanistan, as well as conduct research on Taliban narratives. This trip was highly successful for three main reasons. First, a vast amount of data was collected that would otherwise be difficult (if not impossible) to obtain from the United States. This data was extremely valuable in developing new narratives that strike at the heart of the Pashtun and can affect behavioral changes—particularly whether or not to participate in the IED network chain. This is key in tackling the “left of boom” concept JIEDDO is focused on.

Second, a number of relationships were developed in a variety of locations in Afghanistan that will have long-lasting impacts on future trips to that region. Inroads were made into the Taliban mind itself, an area our human intelligence capabilities have had little success at cracking. With the expectation of future trips to Afghanistan, CCS will be able to solidify and develop greater numbers of contacts and more intimate relationships with people our government has ignored for much too long.

Finally, access to high levels of command leadership was excellent and only promises to get better. Speaking with COMISAF was an honor and a great opportunity to represent JIEDDO and the importance of our mission in Afghanistan. The General recognizes a need for change, and after seven years of misrepresentation, a consistent and persistent effort in Afghanistan is needed more than ever. Future trips to Afghanistan will be undertaken to exploit the vast network of resources developed on this trip.

Highlights of the trip included a special article in Newsweek entitled “Winning in Afghanistan: A Military Analyst on What’s Wrong with U.S. Strategy” (http://www.newsweek.com/id/160439). A briefing was conducted for the ISAF Commanding General, Gen. David McKiernan.

Trip Summary

- **August 3 – 6**
  Our trip began with an initial embed with ODA elements in Kandahar and Helmand.
  - Kandahar: Task Force (TF) -71 (LTC Karsner, Maj. Pat Colloton)
  - Bagram: TF Paladin HQ (COL Jarkowsky, CMD Jon Young, Mr. Ed Mooradian)

- **August 7 – 8**
  Camp Bastion: TF-71
  A brief trip to Camp Bastion provided the opportunity to brief the ODAs there and gather data on their experiences in the field.
• **August 9 – 12**
  Lashkar gah, Helmand: British PRT and Task Force Helmand 16 Brigade HQ
  - MAJ Marshall
  - MAJ Ian MacNeil, S2 Influence
  - Gareth Conway, embedded psychologist
  - Lucas Robinson, political advisor

• **August 13 – 22**
  Kandahar: Canadian PRT, Camp Smith. For a week, we hired a local driver and “fixer” to assist with setting up a number of interviews with tribal elders in Kandahar and its surrounding regions. A list of interviews is below, followed by important points gathered from an initial assessment of those interviews.

  **Interviews:** Joanna Nathan, Senior Analyst, International Crisis Group; Joe Auger, Local Stability Initiatives Team Leader, DAI; COL Woodsworth, Canadian PRT; MAJ Perey, Canadian PRT; Karen Swails, USAID Officer; Sharif (our fixer), Noorzai Pashtun, Kandahar; Dr. Jouri, doctor at clinic in Kandahar; “Deputy” – intermediary with Taliban, works with various news agencies; Whit Mason, Regional Justice Coordinator, UNAMA; Sarah Chayes, Arghand NGO and local policy analyst; Louis Palu, freelance photographer and journalist; Abdul Bari, tribal elder from Maiwand, Ishaqzai Pashtun; Mohammadullah Barakzai, tribal elder from Panjwayi; Nimat Arghandabi, Head of the National Islamic Society of Afghan youth, Mohammedzai tribe; Qari Yousef, Taliban spokesman, southern Afghanistan; Zabidullah Mujahid, Taliban spokesman, eastern Afghanistan.

  **Taliban:** We interviewed Taliban spokesmen from RC South (Qari Youseff) and RC East (Zabidullah Mujahid) for a response to a recent attack on International Rescue Committee (IRC) aid workers in Logar Province on August 16.

  Three Taliban district commanders were interviewed through a hired intermediary with close connections to the Taliban.

• **August 23 – 25**
  Bagram: We had a few days to speak with our sponsors and other individuals while we awaited travel to eastern Afghanistan.

  **Sampling of Interviews:** LTC Eric Edin, Commander CJ-POTF; COL Jeff Jarkowsky, TF-Paladin/CJTF IO; CDR Jon Young, TF-Paladin; LTC Dean Burbridge, CJTF IO; Edward Mooradian, COIC Red Team; SGT Martinez, 2/7 Marines, Helmand.

• **August 26 – 30**
  Asadabad PRT

  **Sampling of Interviews:** Tom Targus, State Department Political Officer; Bruce Dubee, USDA Advisor; Ted Wittenberger, USAID Officer; James Fussel, TF Paladin; Dr. Jeffery Bordin, Red Team Leader; ODA Interpreters, Khalid + 4; Alisonn Blosser, PRT Officer; CDR Dan Dwyer, PRT CO; CPT Rose, TF Paladin; CPT Beasley, EOD; LT Matt Myers, PRT; MSGT Foreman, TF Paladin; various political party representatives – Sayyaf, United Front, Northern Alliance; Governor Wahidi.

• **August 30 – September 4**
  Jalalabad: TF Paladin, IO, PRT

  **Sampling of Interviews:** LTC Paul Donovan, PRT Commander Nangarhar; MAJ Brad Adams, TF Paladin; LTC Herb Bilewski, CIED JAF; MAJ Mike Jackson, CIED JAF; Human Terrain System; Sarah Rahimi, Interpreter, TF Paladin; Chancellor of Jalalabad Medical University; Haji Mohammed Hasan, Provincial Council Representative, Khogiani Tribal elder, Sayyef Party Representative; Provincial Council Representative, Pashai tribal elder; Dr. Nijra Habib, Provincial Council Representative; Abiba Khaker, Provincial Council Representative; Lal Agha Kaker, Mayor of
Jalalabad; Governor Gul Agha Sherzai; Masood Ahmad Azizi, Chief of Staff for Nangarhar Province; Nujayed Ahmad, Political Assistant, PRT Jalalabad; Fazil Hadi, Speaker of Provincial Council, Sayyaf Party Representative; Mirwais Ahmadzai, Director of Eastern Office, AIHRC; NDI Office; Zara, interpreter, PRT Jalalabad; CPT John Morash, JIOC PRT Jalalabad; Sean Waddups, PRT Office Jalalabad.

• September 5 – 12
  Kabul: ISAF HQ, COIN Academy, Camp Warehouse, Camp Eggers

Interviews/Briefs:  ISAF Commanding General, Gen. David McKiernan; Frank Curry, Assymetric Warfare Group, U.S. Army; LTC Robert Spath, CJ POTF; COL Dietger Lather, CJ POTF; Barbara Sotirin, Deputy Director, HQUSACE; Bjorn Delaney, Lincoln Group; Tod Wilson, Office of the Coordinator for Reconstruction and Stabilization, U.S. Department of State; Brian Goodman, OGA; LTC Patrick Kearney, CIED; Christian Harstad, NORNAVSO; Greg Reichman, CENTCOM; Camp Eggers CJ-2; Dr. James Emery, Cultural Anthropologist, Human Terrain System; COL Roger N. Sangvi, Director, CJ2 CTSC; Ray Valez, JIEDDO; Alan Yu, Political Counselor, U.S. Embassy; Paul Fishstein, Director AREU Kabul; Mohammad Yousef, Aschiana; COL John Agoglia and COIN meeting participants; Ayscha Hamdami, Political Advisor, ISAF HQ; Abdullah Amini, Cultural Advisor to COMISAF.

PUBLICATIONS:


PRESENTATIONS:


PROGRAM FOR CULTURE AND CONFLICT STUDIES’ RESEARCH AND WEBSITE

Thomas H. Johnson, Research Professor
Department of National Security Affairs and Program for Culture and Conflict Studies
Sponsor: Rapid Reaction Technology Office

OBJECTIVE: The program has also been assigned by the Rapid Reaction Technology Office (RRTO) to expand the ongoing work of the Program for Culture and Conflict Studies (CCS) in association with the Department of National Security Affairs and the Common Operational Research Environment (CORE) Lab. The intent of this project is to provide timely and current ethnographic, socio-cultural, and geospatial information to deployed units, analysis teams, and other consumers via an open-source platform. Key objectives of the CCS program are to expose and educate deploying and deployed units with necessary
human terrain information prior to and during COIN operations; to support military units and government and non-government organizations involved with development activities in Afghanistan with requested information on the tribal, ethnic, and political context of Afghanistan; and to stay current and expand the knowledge-base on security, political, economic, and other human-terrain issues in Afghanistan.

SUMMARY: This project resulted in a major expansion of our programmatic work concerning culture and conflict. See http://www.nps.edu/programs/ccs/. A new, refereed e-journal, published quarterly, was introduced. New studies and data were also published on the site. During a discussion of “must reads” for the study of Afghanistan for deploying soldiers, Abu Muqawama recently stated on an important COIN blog that “[one] should read EVERYTHING available on the Naval Postgraduate School’s Center for Cultural Studies website, and in particular view the zoom-in map that breaks down areas by sub-tribe affiliations...It has a LOT of useful background and ethnography.” We regularly respond to requests from deployed personnel on a variety of issues of interest. Below are samples of other unsolicited comments concerning our website and work:

- “I heartily endorse his site, his program, and his expertise. INR will concur, as will Secretary Rice and Counselor Cohen. This is a program of significant, immediate operational benefit to both Defense and State and we should be supporting it as much as possible.” Dr. David Kilcullen, April 2008.
- “Your work and website are terrific. I use this resource in my COIN and other classes at USAFA, and to prepare myself and other faculty deploying to Kabul. I find this information and issues essential to faculty and cadets alike. Thanks for your trenchant analyses.”
- “Do you know of a similar program for Iraq? I think the one you have for Afghanistan is terrific, but I am deploying to Iraq and am interested in similar material (the more I can get prior to deployment, the better).”
- “Thanks for the great info! We most certainly need to understand the nature of the conflicts we are currently engaged in Iraq and Afghanistan.”

DETERRENCE AFTER 9/11: NEW DEVELOPMENTS IN THEORY AND PRACTICE
Jeffrey W. Knopf, Associate Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School, Research Initiation Program

OBJECTIVE: Many government officials and commentators stated that September 11 showed that deterrence is no longer applicable to the security threats of the 21st century. This project is a continuation of research to evaluate the claim that deterrence is no longer useful, and to assess how alternative concepts of deterrence might be applied to the main post-9/11 threats: terrorist attacks on the U.S. homeland and weapons of mass destruction (WMD) attacks by rogue states.

SUMMARY: Research in 2008 involved completing two papers and writing a third paper. The first paper traced the post-9/11 evolution of official U.S. policy guidance on deterrence and provided a critical evaluation of how recent U.S. strategy has approached the role of deterrence. This research resulted in a journal article published in 2008.

The second paper completed in 2008 re-assessed the conceptual underpinnings of deterrence and compared post-9/11 debates about deterrence with pre-9/11 debates about deterrence. It found that many of the recent doubts and controversies concerning deterrence are not new. It concluded from this that, just as deterrence had survived past debates and criticisms to remain an element of policy and strategy, so too is deterrence likely to continue to play a role in the post-9/11 world. The paper also argued for developing a broader concept of deterrence as a way to make deterrence more relevant. This part of the research will be published as a chapter in an edited volume scheduled for release in summer 2009.

A third paper resulting from this research involved a comprehensive literature review of scholarly publications on post-9/11 deterrence. It found an emerging scholarly consensus that deterrence remains relevant and a range of interesting new ideas for how to apply deterrence against terrorism. A preliminary
draft was presented at an academic conference, and a revised version was submitted in November for possible journal publication.

**PUBLICATION:**


**PRESENTATIONS:**


**ASIA’S RISING SPACE POWERS: NATIONAL MOTIVATIONS, REGIONAL DYNAMICS, AND IMPLICATIONS FOR THE UNITED STATES (CHANGED FROM A POLITICAL HISTORY OF U.S. NATIONAL SECURITY POLICY)**

James Clay Moltz, Associate Professor

Department of National Security Affairs

Sponsor: Naval Postgraduate School, Research Initiation Program

**OBJECTIVE:** Midway through the first RIP year, the principal investigator (PI) decided to change focus to new research on Asia’s emerging space programs, their motivations, and the implications for U.S. national security. This project aims to conduct four major case studies (China, India, South Korea, and Japan) on national space capabilities, as well as a collection of secondary case studies (Pakistan, North Korea, Iran, etc.). Analysis will also be conducted from a comparative conceptual approach to explain individual-country motivations and from a national-security-policy perspective on implications for U.S. space security.

**SUMMARY:** During spring 2008, the PI began preliminary research for the case studies and outlined the book project, including working out structural details of the various chapters and writing a detailed summary for each. In early September 2008, the PI participated in a conference in Vancouver, Canada, on the Chinese space program, conducting interviews with Chinese space officials and experts. The PI traveled to South Korea in late September 2008 to continue research, interviewing South Korean space experts and officials and spending a day at the Korean Aerospace Research Institute (their NASA equivalent) in Taejon. In late fall, the PI began writing several chapters of the book and continued collecting research materials on the various case studies.

Throughout 2008, the PI continued to develop and share preliminary findings at various venues. The PI also incorporated relevant materials on Asian space programs into the course “Space and National Security” in the 2008 fall quarter.

**PRESENTATIONS:**


FACILITATING COOPERATIVE RESEARCH AND EXCHANGES BETWEEN THE NASA AMES RESEARCH CENTER AND THE NAVAL POSTGRADUATE SCHOOL

James Clay Moltz, Associate Professor
Department of National Security Affairs
Sponsor: NASA Ames Research Center

OBJECTIVE: To conduct a series of related activities to support collaboration between the Naval Postgraduate School (NPS) and the NASA-Ames Research Center (ARC) from July 2007 to June 2008. This will involve: 1) supervising and participating in small, cooperative research projects in the areas of small spacecraft, space traffic management, international cooperation in human spaceflight, lunar governance, and other space-related topics; 2) helping promote personnel exchanges between NPS and NASA-Ames, including establishing a monthly presentation/discussion session (the Space Futures Working Group); 3) completing an individual research project on a topic to be determined in cooperation with NASA-ARC personnel; and 4) completing a final report for NASA-Ames and NPS on the status of cooperation at the end of the project in June 2008.

SUMMARY: Successfully conducted and chaired monthly meetings of the Space Futures Working Group; completed a written research paper on “Lunar Governance Challenges: Human Settlement of the Moon in Historical Context” (now being considered for publication in Strategic Studies Quarterly); and delivered a final report on collaborative efforts between NPS and NASA-Ames in the space field.

SUPPORTING COLLABORATION BETWEEN THE NASA AMES RESEARCH CENTER AND THE NAVAL POSTGRADUATE SCHOOL:

THE SPACE FUTURES WORKING GROUP

James Clay Moltz, Associate Professor
Department of National Security Affairs
Sponsor: NASA Ames Research Center

OBJECTIVE: This project will involve support of NASA-Ames research in the area of space policy and collaboration with the Naval Postgraduate School (NPS). The goals of this research include: 1) helping facilitate cooperation between the Ames Research Center and NPS in education and research relevant to future U.S. space policy, 2) chairing and helping manage the activities of the Space Futures Working Group, and 3) completing four short reports on issues affecting future U.S. space policy.

SUMMARY: In addition to organizing and chairing monthly meetings of the Space Futures Working Group at NASA-Ames, the 2008 deliverables included co-authoring/co-editing four policy papers prepared with other members of the group on options for future U.S. space policy in four areas: 1) space security; 2) space, climate change, and the environment; 3) space science; and 4) human spaceflight. These papers were presented to senior staff at the White House Office of Science and Technology Policy (OSTP) in November 2008 (by request) by the principal investigator and one NASA-Ames co-author: the presentations were designed to help inform deliberations at OSTP regarding the presidential transition in the area of space policy.
PUBLICATIONS:


THE RUSSIAN-AMERICAN STUDY GROUP ON STRATEGIC CRISIS MANAGEMENT

Mikhail Tsypkin, Associate Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To investigate the possibilities of future U.S.–Russian cooperation in advancing strategic stability in the Asia-Pacific region. This is part of a multi-year project.

SUMMARY: Conducted a U.S.–Russian workshop on “Perceptions of Strategic Stability and Security in the Asian/Pacific Region.” The workshop was attended by U.S. and Russian academic experts on Asian security. The period of performance is 14 May 2008 to 14 May 2009.

KEYWORDS: Russia, China, North Korea, South Korea, India, Pakistan, Military, Security, Nuclear, Weapons of Mass Destruction, Terrorism

THE NAVAL POSTGRADUATE SCHOOL ASIA CONFERENCE

Christopher P. Twomey, Assistant Professor
Department of National Security Affairs
Sponsor: Office of the Secretary of Defense (Policy)

OBJECTIVE: This classified project addresses important issues regarding security in East Asia. The 60-page conference report is available upon request at the SECRET level.

U.S.-CHINA STRATEGIC DIALOGUE, PHASE IV

Christopher P. Twomey, Assistant Professor
Department of National Security Affairs

OBJECTIVE: This project brings together Chinese and American national security experts for a dialogue on nuclear strategy, arms control, missile defense, and nuclear proliferation in order to improve mutual understanding and reduce the possibility of political or military conflict between China and the United States.

The U.S.-China Strategic Dialogue brings together Chinese and U.S. strategic experts in their personal capacities to discuss the role of nuclear weapons in Sino-American relations, with the aim of minimizing mutual misunderstanding and identifying practical steps for bilateral cooperation. This fourth annual meeting of track-two dialogues promises to be highly successful; the meeting will be held in March 2009.
COMPETITION DYNAMICS AND PARTY SYSTEM EVOLUTION IN JAPAN

Robert Weiner, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School, Research Initiation Program

OBJECTIVE: To analyze party and electoral competition and party system development in Japan: how parties pursue and avoid competition, how new opposition forces are evolving, and how these dynamics shape policy change in Japan, including change in foreign policy and U.S.-Japan alliance management. This is a continuing project.

SUMMARY: Project work in 2008 proceeded largely through on-campus research, supplemented by a fieldwork trip to Tokyo. Significant progress was made on a book manuscript examining party competition in Japan and in democracies more generally ( provisionally titled No Contest: Anti-Competition in Japan and Other “Competitive” Party Systems). Preliminary drafts of all chapters were completed in preparation for submission to a university press (Stanford University Press has expressed interest) in 2009. The research also produced two edited-volume chapters on its implications for competitiveness in national and local Japanese elections (one published in 2008 and the other submitted in 2008 and currently in proofs for publication in 2009). Project work also involved constructing an original database of the Democratic Party of Japan’s national-level candidates and their ideological leanings, which supported the drafting of a third edited-volume chapter on the party’s ideological, tactical, and geographical evolution. Portions of the research were presented at the annual meeting of the Association for Asian Studies and in an invited lecture at the University of California-Berkeley. Another presentation related to the research was solicited and provisionally scheduled by Stanford University; this presentation was postponed until 2009 due to the rescheduling of previously anticipated Japanese elections.

PRESENTATIONS:


CONTRIBUTIONS TO BOOKS:


EUROPEAN SECURITY AND NATO NUCLEAR POLICY
David S. Yost, Professor
Department of National Security Affairs
Sponsor: Deputy Assistant to the Secretary of Defense (Nuclear Matters),
Office of the Secretary of Defense

OBJECTIVE: To advance the understanding of European security-policy developments, notably with regard to NATO nuclear-weapons policy. This includes matters such as nuclear deterrence doctrine in the alliance and policy debates in major NATO European countries.

SUMMARY: Changes in the international security environment since the collapse of the Soviet empire in 1989-1991 have created a new context for the analysis of NATO nuclear-weapons policy and theories of extended deterrence. The issues include the evolving purposes of the NATO nuclear-force posture, questions of doctrine and declaratory policy, and the future of relevant, international, arms-control regimes. Another important set of issues concerns the relevance for the alliance of the defense policy goals articulated by the United States in the Quadrennial Defense Review and the Nuclear Posture Review. The continuing proliferation of weapons of mass destruction and developments in Russia and elsewhere in Eurasia have also raised questions concerning the context for NATO policy-making.

PUBLICATION:

PRESENTATION:

THESES DIRECTED:


NATO AND TAILORED DETERRENCE, PHASE I
David S. Yost, Professor
Department of National Security Affairs

OBJECTIVE: To gain a better understanding of allied views on deterrence policy issues and to examine the relevance for the alliance of the concept of “tailored deterrence” in particular.

SUMMARY: The project investigated what the United States and its NATO allies can do to improve the Alliance’s deterrence posture and adjust it to the requirements of specific contingencies involving particular adversaries. This included the pursuit of a greater consensus within the Alliance regarding future deterrence requirements, notably in reference to nuclear and missile defense policy and the upcoming NATO Strategic Concept review. The policy concerns included new force modernization choices (weapons and platforms), new threats (for instance, state sponsors of terrorism and regional and major powers), new non-nuclear strike and defensive capabilities (notably missile defenses), and new assessments of arms-control measures (including the future of START, the INF Treaty, and the NPT).

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PRESENTATIONS:


DEPARTMENT OF NATIONAL SECURITY AFFAIRS

2008
Faculty Publications and Presentations
PUBLICATIONS


CONFERENCE PUBLICATIONS


PRESENTATIONS


Johnson, T.H., “Possible Future for Afghanistan Conference,” Meridian International Center, Washington, D.C., 5 May 2008 (invited). (Meridian assisted the U.S. Department of State in coordinating this seminar.)


Johnson, T.H., “U.S.-Pakistan Strategic Partnership: A Track-Two Dialogue on Counterterrorism Cooperation,” Project organized by the Center for Contemporary Conflict, the Naval Postgraduate School, and Pakistan’s National Defense University with support from the U.S. National Intelligence Council, Naval Postgraduate School, 24-25 June 2008 (invited participant).

Johnson, T.H., Wilton Park Conference on the Federally Administered Tribal Areas (FATA), in cooperation with the U.K. government, acting through its High Commission in Islamabad, organized a four-day meeting on key governance issues affecting FATA to identify policy options for more effective management of the region and its border security, 6-9 November 2008 (invited participant).


BOOKS

Clunan, A.L., Lavoy, P.R., and Martin, S.B. (Eds.), Terrorism, War, or Disease? Unraveling the Use of Biological Weapons, Stanford University Press, August 2008.

CONTRIBUTIONS TO BOOKS


GRADUATE SCHOOL OF OPERATIONAL AND INFORMATION SCIENCES

PETER PURDUE
DEAN
DEPARTMENT OF
COMPUTER SCIENCE

PETER J. DENNING
CHAIR
OVERVIEW:

The Department of Computer Science provides graduate training and education in major areas of computer science. Both basic and advanced graduate courses are offered. Course work and research lead to either the degree of Master of Science, Doctor of Philosophy, or Master of Computing Technology. The requirements to complete either program are rigorous and 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
- Master of Computing Technology and associated certificates
- 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 Valdis Berzins, Professor Ted Lewis, Professor Luqi, Associate Professor Mikhail Auguston, Associate Professor Doron Drusinsky, Associate Professor J. Bret Michael, Associate Professor Man-Tak Shing, Senior Lecturer Loren Peitso, and Visiting Professor Richard Riehle

Databases:
Associate Professor C.T. Otani and Research Associate Arijit Das

Information Security:
Professor Cynthia E. Irvine, Associate Professor George Dinolt, Research Associate Professor Karen Burke, Research Associate Professor William Murray, Research Associate Paul Clark, Lecturer Scott Cote, Senior Lecturer Chris Eagle, Lecturer J.D. Fulp, Senior Lecturer Daniel Warren, Research Associate Thuy Nguyen, Research Associate Tim Vidas, and Research Associate Charles Prince

Autonomous Systems:
Professor Neil Rowe, Associate Professor Chris Darken, Associate Professor Craig Martell, Assistant Professor Mathias Kolsch, Assistant Professor Kevin Squire, and Research Associate Tad Masek

MOVES Institute (Modeling, Virtual Environments, and Simulation):
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Networks:
Professor Gurminder Singh, Associate Professor G.M. Lundy, Associate Professor Geoffrey Xie, and Research Associate John Gibson
Programming Languages:
Associate Professor Dennis Volpano

RESEARCH FACILITIES:

- Computer Science Learning Resource Center
- Introductory Computer Security Laboratory
- Computer Information Security Laboratory
- Public Key Infrastructure Laboratory
- Introductory PC Network Laboratory
- Intermediate Local Area Network Laboratory
- Wireless and Mobile Computing Laboratory
- Autonomous Robotics Coordination Laboratory
- Software Engineering Laboratory
- MOVES Institute (Modeling, Virtual Environments, and Simulation)

RESEARCH CENTERS:

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

RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include 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:

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**Project Summaries**
MODELING AMBIGUITY THROUGH FALSE POSITIVE PERCEPTIONS

Christian Darken, Associate Professor
Department of Computer Science
Sponsor: Naval Modeling and Simulation Office

OBJECTIVE: To support the 2006 C4ISR FACT Critical Research Area to develop the knowledge, algorithms, and data to represent the effect of ambiguity on decision-making in the area of inaccurate identification/classification/affiliation of acquired entities.

SUMMARY: This project developed data, models, and methodologies to make the levels of information ambiguity within simulations more realistic by implementing “false positive” acquisitions. In doing so, it developed data, models, and algorithms related both to modeling ambiguity in simulation and to modeling visual perception more accurately. By permitting the possibility of false-positive target acquisitions, the results supported the injection of ambiguity into simulated situational awareness in a realistic manner: through errors in perception. The results also complemented the development of extensions to the ACQUIRE algorithm for use in urban environments to more accurately represent the difficulty of target acquisition in MOUT.

PRESENTATION:


THESSES DIRECTED:


DESIGNING SECURE MULTI-CORE SYSTEMS ON RECONFIGURABLE HARDWARE

Theodore D. Huffmire, Assistant Professor
Department of Computer Science
Sponsor: Research Initiation Program

OBJECTIVE: To develop design techniques to enhance the security of multi-core systems; and to evaluate these strategies on reconfigurable devices across a variety of classes of designs. The principal investigator (PI) is developing a model for determining the optimal communication architecture for a given application. To achieve this goal, the PI is building a testbed for evaluating different architectural alternatives for the physical implementation of computations. In order to develop a mechanism for managing the communication between multiple computing cores, the PI is developing architectural models that clearly describe different approaches and that help investigate, verify, and compare their security properties. The communication management scheme for multi-core systems will determine the optimal set of security and communication foundational mechanisms for a specific application.

SUMMARY: In CY2008, the PI worked on a novel technique that uses 3D integration to augment a commodity integrated circuit after fabrication with a separate layer of security circuitry. In addition to filing for a patent, the PI submitted multiple reimbursable proposals to the NSF, and spoke to USSTRATCOM, DARPA, and the NSA about the technique. The PI also submitted white papers to NRO and AFOSR. In addition, the PI studied the problem of security for on-chip interconnection networks for multi-core hardware. Network-on-Chip (NoC) interconnect will be necessary for future micro-architectures with large numbers of computational cores. In order to facilitate efficient and secure communication
between cores, in CY2009 the PI will develop an architectural simulator for exploring the design space of NoC security architectures. Progress has been made in learning how to use embedded design tools to program FPGA development boards. The PI used the equipment budget to purchase workstations, field-programmable gate array (FPGA) development boards, and design software for the lab. The PI used the travel budget to travel to relevant conferences and has also published in peer-reviewed venues. The conferences have been an opportunity to learn about hardware-oriented security and to meet experts from DAFCA, ITT, Element CXI, the University of Washington, Virginia Tech, and others.

PUBLICATIONS:


CONFERENCE PUBLICATIONS:


PRESENTATIONS:


PATENT:


THESIS DIRECTED:

COMPUTER SCIENCE

ADAPTIVE SECURITY AND SEPARATION IN RECONFIGURABLE HARDWARE
Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: To enhance the logical structure and internal management of reconfigurable hardware to enforce a dynamic information-protection policy with a high degree of assurance. Toward this end, an interdisciplinary approach is proposed that takes important new ideas regarding adaptable security and separation kernels and applies them to the control and management of a modern reconfigurable device, the field-programmable gate array (FPGA). This research will result in provable and adaptable compartmentalization within reconfigurable devices. The project will be organized into three primary research thrusts: 1) the design of an architecture and methods to control dynamic logic changes and to ensure the secure configuration of logic modules, 2) the design of structures and methods to mediate runtime access to shared resources (such as memory), and 3) the design of methods for dynamic

SUMMARY: From Bluetooth transceivers to the NASA Mars Rover, FPGAs have become one of the mainstays of embedded design. By blurring the line between software and hardware, reconfigurable devices strike a balance between the raw, high speed of custom silicon and the post-fabrication flexibility of general-purpose processors. While this flexibility is a boon for embedded system developers, who can now rapidly prototype and deploy solutions with performance approaching custom designs, this hardware malleability can unfortunately be twisted to disrupt critical operations, snoop on supposedly secure channels, or even to physically melt a device. Creating systems that are both efficient and flexible, yet fundamentally sound from a security point of view, is an exceedingly challenging endeavor for both researchers and practitioners; all too often the security aspects of a reconfigurable design are left until far too late in the design process—the resulting systems are protected only by their obscurity.

Over the past year the principle investigators (PIs) have continued to hone methods and disseminate results to the computer security, embedded systems, FPGA, CAD, and computer architecture communities. Specifically, over the last year a new, more powerful, and more efficient method for providing separation in FPGA systems has been developed. The original idea, presented last year in the premier security conference IEEE Security and Privacy, has now been extended through the creation of a less wasteful method for creating dead-zones between critical components (the “Moats” in the original paper). In addition, several new test platforms were created to demonstrate that this is really a feasible mechanism in embedded systems, including a red-black multiprocessor system and fingerprint reader. Additionally, researchers have concentrated heavily over the last year in disseminating these results to a broad community of researchers and practitioners through journal publications in security and embedded system design—in fact, the PIs signed a book contract that will bring these and other methods to an even larger audience.

PUBLICATIONS:


CONFERENCE PUBLICATIONS:


International Workshop on Hardware-Oriented Security and Trust (HOST-2008), Anaheim, California, June 2008 (extended abstract).


PRESENTATIONS:


KEYWORDS: FPGA, Hardware Security, High Assurance

AN ANALYSIS OF THE INFORMATION ASSURANCE IMPACT OF SELECTED EMERGING TECHNOLOGIES: PLANNING

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: To establish a framework for a set of activities to be conducted to investigate the information assurance impacts of emerging technologies on behalf of the National Security Agency (NSA). The work will include the development of a detailed plan for technology studies: a set of selected analyses will be used as pilot analyses to validate the framework.

SUMMARY: Rapidly emerging technology can present significant information assurance challenges to organizations charged with protection of information. As one of the primary providers of information assurance expertise and technology to the Department of Defense (DoD), the National Security Agency must keep ahead of emerging technologies in ways that permit it to work with both vendors and users to develop components that will enhance, rather than detract from, the national security posture.

It described criteria for innovation and carefully distinguished innovation from invention, where the former takes place largely in the commercial sector and the latter may occur in academe. Instead of focusing on products specifically developed to answer information assurance requirements, the analysis attempted to provide a framework within which large information technology domains could be addressed. Once innovations within a selected domain were identified, then their information assurance impact would be considered. Details of the proposed approach were described, including expertise requirements and tools to be developed within the context of subsequent activity on this effort.

KEYWORDS: Emerging Technology, Information Assurance
A CYBER-DEFENSE INITIATIVE WORKSHOP: RESEARCH AND TECHNOLOGY FRAMEWORK AND PLAN
Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Science Foundation, Naval Postgraduate School

OBJECTIVE: To develop a framework for moving forward with well coordinated technological, societal, and research activities needed to reach the 10-year objective of transforming the cyber-infrastructure to be resistant to attack. The workshop brought together a relatively small group of experts from government, industry, and academe in secure computer systems and networks. They addressed, at a high level, a broad range of technical areas and issues associated with the lifecycle processes for large, secure systems. Concerns included elicitation of requirements, specification, design, implementation, configuration management, tests and analysis, certification, deployment, and maintenance. The primary product of the workshop will be a report describing the framework and plan developed by participants.

SUMMARY: This workshop, held at the Naval Postgraduate School in Monterey, California, from 3-7 December 2007, was a continuation of an ongoing sequence of meetings in connection with a “grass roots” effort to create a 10-year research plan for the protection of national, cyber-critical infrastructure from strategic damage. The plan supports our vision—to transform the cyber-infrastructure to be resistant to attack so that critical, national interests are protected from catastrophic damage and our society can confidently adopt new technological advances. This would be accomplished in such a way as to create a lever to enhance U.S. high-tech competitiveness, attract top students into strong educational programs, and strengthen government, industry, and academic research.

The workshop developed a set of desired end-states that a national research agenda would enable: continuity of critical information-infrastructure operations; well-defended critical assets; local/global cyber situation awareness; confidentiality-preserving systems; extensible systems that safely embrace new technology; and metrics-based quantifiable security.

Key research activities to support these end-states were identified: embrace architectural principles that enable the creation and operation of secure systems; design systems to satisfy critical mission requirements; create and combine metrics-driven security analysis, simulations, and testing; exploit authentication and attestation mechanisms to establish trust and justify suspicion; develop human capital; and initiate research in key technology areas.

Recommendations for next steps include a series of workshops focusing on specific topics in greater technical depth; comparison of workshop results against “traditional” cyber-security requirements areas; end-state quantification; understand change in the context of the commercial sector; and a series of subsequent workshops.

CONFERENCE PUBLICATION:

KEYWORDS: Cyber Security, Research Agenda
create reports and documentation that can be incorporated into the Computing Platform Architecture and Security Criteria (CPASC) specification for the HAP Program.

SUMMARY: The Naval Postgraduate School (NPS) was part of a small, collaborative team that developed the High-Assurance Platform (HAP) Program Overview Document (Version 1.0, 7 February 2008). Following the creation of the HAP Program Overview, NPS was again part of a small team that developed the HAP Release 2-C Computing Platform Architecture and Security Criteria (CPC), which was delivered to the sponsor for review and distribution to selected vendors for comment and collaboration. It included reviews of existing requirements specifications for HAP Release 2; development of security requirements for information flow and resource access controls, trusted path and trusted channel, reverse tunneling, user identification and authentication, user session management, and architectural protection; and work on security requirements for attestation, provisioning, network access control, and virtualization of the Trusted Platform Module in the context of HAP.

CONFERENCE PUBLICATION:

PRESENTATION:

A HIGH-ASSURANCE TESTBED FOR MULTILEVEL INTEROPERABILITY:
RESEARCH STAGE 2-3, CONTRACT PHASE V
Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Reconnaissance Office

OBJECTIVE: The purpose of the Monterey Security Architecture (MYSEA) Multilevel Testbed, a multi-year project, is to develop high-assurance security services and integrated operating-system mechanisms that protect distributed multi-domain computing environments from malicious code and other attacks. These security services and mechanisms extend and interoperate with existing applications and open-source operating systems, providing new capabilities for composing secure, distributed systems using commercial, off-the-shelf components. The latter objective results from the realization that unless a secure system offers users convenient interfaces equivalent to those used when handling routine information, the secure system will fail due to lack of user acceptability.

SUMMARY: A prototype of a network with high-assurance security services and integrated operating-system mechanisms protecting a distributed, multi-domain, computing environment was developed. The effort provided concrete results in the following areas:

User access via unmodified commercial OS and applications. Users on commercial workstations will be able to access multi-domain information managed by the remote, trusted OS, without modification of workstation operating systems or applications.

Transparent session-level access to multiple domains. Users can access data at and below their classified session levels, providing simultaneous access to multiple data domains, as authorized by policy. This feature is provided by security policy-aware protocol servers, which are added to the system with only the minimal modification required for a typical platform port and are made policy-aware with some additional effort.

Remote trusted-path access to a multi-domain operating system. User authentication and session security attribute negotiation with the multi-domain OS occurs by way of a trusted path between the user and the trusted OS extension, as well as between the trusted OS extension and the trusted OS. Users are assured that the authentication and negotiations are with the trusted OS and not with masquerading malicious software executing in other systems on the network, on the workstation, or as
unvetted applications on the trusted OS.

Policy-driven dynamic network-security services. Policy changes at the middleware or application level, for example as the result of changes in network situational mode or quality-of-service considerations, are automatically manifested in network connectivity maps and communication security settings (e.g., IPsec) managed within the trusted OS. Intrusion detection systems within the testbed currently act as triggers for changes by the dynamic security policy mechanism.

Single sign-on to access multiple trusted servers. From a single session, the user can access multiple application servers on different trusted OSs, without requiring separate re-authentication.

CONFERENCE PUBLICATION:


PRESENTATION:


TECHNICAL REPORTS:


THESIS DIRECTED:


KEYWORDS: Information Assurance, Multilevel Security, Testbed, Cross Domain Solutions

INFORMATION ASSURANCE SCHOLARSHIP PROGRAM SUPPORT–2008
Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: Office of the Secretary of Defense
Executive Agent: National Security Agency

OBJECTIVE: To support student research and studies in information assurance. This work will be conducted as part of the multi-year Information Assurance Scholarship Program (IASP). Faculty and staff in the Center for Information Systems Security Studies and Research (CISR) at the Naval Postgraduate School (NPS) will provide student participants with guidance and material support relating to prerequisite studies and research leading to Master’s and Ph.D. degrees in computer science.
SUMMARY: In 2008, several students participated in the Information Assurance Scholarship Program: three Ph.D. students and three Master’s students. Each student completes either a thesis project or dissertation in collaboration with other students, faculty, and research staff. Thesis research permits in-depth exploration of a topic, ensures an appreciation of the unsolved problems and challenges in information assurance, and provides valuable experience in critical thinking and writing.

This work strengthens and enlarges Department of Defense (DoD) human capital in information assurance (IA). With preparation provided through a broad course of study enhanced by special emphasis on computer security and focused research on a pertinent topic in IA, NPS IASP graduates are uniquely qualified to serve in managerial and high technical-level positions throughout the Department of Defense.

CONFERENCE PUBLICATION:


PRESENTATION:


THESES DIRECTED:


KEYWORDS: Information Assurance, Cyber Security

INFORMATION ASSURANCE THROUGH SCHOLARSHIP AND SERVICE

Cynthia E. Irvine, Professor

Department of Computer Science

Sponsor: National Science Foundation

OBJECTIVE: 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: As of December 2008, the Naval Postgraduate School (NPS) CISR SFS program has graduated 68 Federal Cyber Corps scholarship recipients. Graduates of the program have acquired positions in the federal sector, with jobs at the National Security Agency, the Space and Naval Warfare Systems Command, the Federal Deposit Insurance Corporation, the Department of Housing and Urban Development, the Defense Manpower Data Center, the Naval Research Lab, the National Criminal Intelligence Service, the Central Intelligence Agency, and Sandia National Laboratory.

To date, the Center for Information Systems Security Studies and Research at NPS has been successful in placing 100% of its SFS graduates into OPM-approved positions. Many students have also completed 3-6 month internships with approved agencies.

Each student completes a thesis project in collaboration with other students, faculty, and research staff. Thesis research permits in-depth exploration of a topic and ensures an appreciation of the unsolved problems and challenges in information assurance, as well as providing valuable experience in critical thinking and writing.
A SECURE CORE FOR TRUSTWORTHY COMMODITY COMPUTING AND COMMUNICATION
Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: To investigate a minimal set of architectural and functional features required for trustworthy operation of mobile computing devices. A clean-slate design approach was proposed to achieve suitable levels of security, synergistically integrating the design of the three key components at the heart of modern mobile computing platforms: the processor hardware, the operating-system kernel software, and the networking interface. Tasks included a systematic analysis of integrated security requirements, design and architecture for a secure core, and development of experiments and prototypes to demonstrate the types and levels of security achievable for commodity platforms using this secure core.

SUMMARY: To address the security shortcomings of existing IT systems, the Transient Trust Security Architecture and related operational concepts for securely managing sensitive information during emergencies has been developed. The key innovative properties of the Transient Trust Architecture are: a means of providing secure, temporary access to sensitive information which can also completely revoke the information after the emergency; a dedicated environment for the use of high-integrity applications (such as for the trusted signing of documents); and a means of directly utilizing the high-assurance capabilities of a separation kernel to control communication and other interactions between security domains.

The target platform for design and experimentation is a hand-held device, called the E-Device. The architecture provides a rigorous partitioning of security domains and hosts user applications in both normal and emergency contexts so that first responders can be familiar with the E-Device and so that the device can be readily available for emergencies.

The architectural support for trusted communication channels, including a remote trusted path between a crisis authority and the E-Device, as well as trusted display channels in the E-Device, have been developed. The effort has integrated hardware-based key-generation into the trusted channel mechanism to protect the storage of channel keys and ensure the authentication of first responders who will gain access to emergency information. A comprehensive design for the management of distributed emergency state, which is critical for effective emergency response, was defined. The Trusted Application Display protects the communication between security application software even in the face of a corrupted OS. The E-Device supports the multifaceted containment of emergency data and reliable revocation of access at the end of the emergency, using a combination of hardware and software mechanisms. Finally, a prototype was built that validates key concepts of the architecture, indicating the feasibility of using commodity mobile and wearable platforms for secure emergency-response data dissemination.

The significance of this project is that it has established a means of providing affordable, highly secure, information processing in a small, portable form factor. The project shows that a coherent security architecture can be based on a simple separation kernel, without undue dependency on application
programs for the enforcement of the security policy; and that emergency access to information can be spatially and temporally confined to prevent unwanted propagation and to enable complete revocation. This is transformative research showing how fundamental security hooks can be built into commodity devices. It opens up new research directions in designing security into all IT designs: computer hardware, software, and networking architecture. Some of the achievements are in the Transient Trust Computer Architecture, minimalist Trusted Computing Bases containing microprocessor hardware and Trusted Management Layer software, secure caches that prevent side-channel information leakage, deployable memory integrity solutions, non-copyable disks, and secure key-establishment in mobile ad hoc networks.

CONFERENCE PUBLICATIONS:


PRESENTATIONS:


TECHNICAL REPORTS:


THESIS DIRECTED:


PATENT:


KEYWORDS: Information Assurance, Security Architecture, High Assurance, Transient Trust
OBJECTIVE: To explore three areas that promise to result in high impact advances in the areas of protocol analysis of protected communications channels, the application of authorship attribution techniques to ensure the proper filtering of information prior to downgrade by cross domain guards, and an automated framework for the static analysis of covert channels and other system security properties.

SUMMARY: Within a multilevel secure (MLS) system, unauthorized information flows can result from malicious software exploiting covert channels and overt channels caused by flaws in design and implementation. To address this problem, the principal investigators have developed a precise, formal definition for information flow that relies on control dependency tracing and extends classic and follow-on work in secure information flow. A security Domain Model (DM), designed in the Alloy formal specification language, for conducting static analysis of programs to identify illicit information flows, control dependency flaws, and covert channel vulnerabilities was created. The model includes a formal definition for trusted subjects, which are granted extraordinary privileges to perform system operations that require relaxation of the mandatory access control (MAC) policy mechanisms imposed on normal subjects, but are trusted to behave benignly and not degrade system security. The DM defines the concepts of program state, information flow, and security policy rules, and specifies the behavior of a target program. Each DM is compiled from a representation of the target program, written in a specialized Implementation Modeling Language (IML), and a specification of the security policy, written in the Alloy language. The Alloy Analyzer tool was used to perform static analysis of the DM to detect potential security policy violations in the target program. Presently, the small scope hypothesis limits the size of the code base that can be analyzed using these techniques.

Text-based chat systems are widely used within the Department of Defense, but the standard systems available do not provide robust capabilities for search, information retrieval, or information assurance. This research explored methods for the extraction of conversation threads from text-based chat systems in order to enable such tasks. As part of the research, over 20,000 Internet Relay Chat posts with conversation thread information were manually annotated, and a probabilistic model for automatically classifying posts according to conversation thread was constructed. An algorithm was developed for extracting these conversation threads from the chat session in order to form discrete documents that may be used in a vector space model information-retrieval system. This technique was elaborated to show how it can be used to support search and data mining systems, as well as auditing tasks and guard functions in a security system. Using the developed probabilistic models, classification results on par with those of human annotators were achieved.

CONFERENCE PUBLICATIONS:


COMPUTER SCIENCE

PRESENTATIONS:


THESES DIRECTED:


KEYWORDS: Static Analysis, Multilevel Security, Cross Domain Solutions, Text-Based Chat

TRAINING TOOLS AND EDUCATIONAL PROGRAM DEVELOPMENT FOR IDENTITY MANAGEMENT

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: Deputy Assistant Secretary of the Navy

OBJECTIVE: To develop educational tools and courses to support an educational program in identity management. A set of courses will be developed for two degree programs at the Naval Postgraduate School: Computer Science and Information Systems. The courses to be developed will include technical, policy, and operational topics in identity management. An objective is to create a program in which participants may take a limited set of identity management courses or an entire degree in either Computer Science or Information Systems. The Navy will leverage its investment in the information assurance training and education game CyberCIEGE by extending the tool to include identity management scenarios, devices, and movie clips. This work will include focus groups on identity management, as well as participation in an identity management conference.

SUMMARY: Most of the sponsored effort was for course and curriculum development, which is not reported here. Work on CyberCIEGE falls into the research domain.

The CyberCIEGE game engine was extended to include identity management devices, including biometric scanners and card readers. Physical access control functions within the game were expanded to include checkpoints that tie player choices regarding access control mechanisms to the behavior of game characters. The game-engine asset-goal abstractions were extended to represent the need to access databases from identity management devices, including access-control data references and logging.

Logical access control to workstations and servers was expanded to provide a user authentication and account management scheme that supports authentication servers and the use of identity management devices to access workstations. Authorization profiles were added to permit “visiting” authorized users to access network resources without necessarily having explicit computer accounts at the local enterprise.
Virtual private network (VPN) support within the game was extended to include VPN clients and connection profiles that constrain traffic within a VPN.

Scenarios were created and expanded to include identity management devices and game engine logic. A new scenario illustrating issues related to controlling and monitoring physical access to a military base was created. The user authentication scenario was reworked and expanded to illustrate the challenge of authenticating users to computers in a range of circumstances, including the use of one time passwords and biometric authentication devices. The VPN scenario was reworked to illustrate the use of VPN clients and the principle of least privilege within an enterprise. Player feedback mechanisms were expanded and game interfaces were enhanced to simplify player navigation within the virtual environment and to make it easier for players to assess the circumstances within which they must make decisions.

PRESENTATIONS:


KEYWORDS: Identity Management, Information Assurance, Education, Awareness, Technical Infrastructure, Policy, Operational Systems

THE TRUSTED COMPUTING EXEMPLAR: LEAST PRIVILEGE SEPARATION KERNEL - VERTICAL SLICE

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: To conduct research that will result in the construction of a component that meets the criteria for evaluation at the highest levels of assurance. The component will be a vertical slice of a Least Privilege Separation Kernel: the KPSK-VS. The vertical slice will be a usable, high-assurance system with all documentation required for an EAL 7 evaluation against the U.S. Government Protection Profile for Separation Kernels in Environments Requiring High Robustness. It will include the LPSK-VS lifecycle plans and procedures, design documentation, implementation, formal work, user documentation, reference application, and test documentation. Research will include analysis and design of kernel functions to support resource sharing among partitions as permitted by a transient trust policy, which allows emergency access to critical data.

SUMMARY: The Trusted Computing Exemplar Least Privilege Separation Kernel was organized into three phases: Prototype, Vertical Slice, and Phase 1. The Prototype Phase was completed in the spring of 2008. Functional kernel features of the initial prototype included multiple partitions, resource allocation, timer-based scheduling, and I/O interrupt handling. Specifications and designs were developed that cover both Phase 1 and the Vertical Slice, where the latter constitutes a subset of the former. This work included synchronization primitives and secure attention key detection and reflection. A Trusted Services Layer was designed and prototyped to support secure attention key management and provision of screen and keyboard services to the partitions in a user-friendly manner. Tools and templates to support creation of the Vertical Slice and the evaluation were created.
COMPUTER SCIENCE

PUBLICATIONS:


PRESENTATIONS:


KEYWORDS: Least Privilege, Separation Kernel, High Assurance, Multilevel Security

ADAPTIVE AUTOMATED DETECTION OF EMPLACEMENT OF EXPLOSIVE DEVICES

Neil Rowe, Professor

Department of Computer Science

Sponsor: National Science Foundation, Explosives and Related Threats Exploratory Research Program

OBJECTIVE: To study methods for detecting emplacement of improvised explosive devices using a field of sensors.

SUMMARY: Work in 2007 involved setting up a sensor network and measuring the effectiveness of magnetic sensors in detecting movement within the field. The principal investigators also constructed a software simulator for sensor networks similar to those implemented to enable faster testing.

CONFERENCE PUBLICATIONS:


THESIS DIRECTED:

DEPARTMENT OF 
COMPUTER SCIENCE

2008 
Faculty Publications 
and Presentations


**CONFERENCE PUBLICATIONS**


**PRESENTATIONS**


Irvine, C.E., “The NPS Identity Management Education Program (IMEP),” Identity Protection and Management Senior Coordinating Group, Fort Ord, California, 8 October 2008 (invited).


Rowe, N.C., Workshop on Metaphors for Cybersecurity, Cyber Fest 08, Sandia Laboratories, Albuquerque, New Mexico, 27-30 May 2008 (invited participant).


CONTRIBUTIONS TO BOOKS


TECHNICAL REPORTS


PATENT


SOFTWARE PRODUCT

Irvine, C.E., Ongoing updates to and version of CyberCIEGE.
DEPARTMENT OF DEFENSE ANALYSIS

GORDON MCCORMICK
CHAIR
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
• Irregular Warfare

RESEARCH CENTER:

• Center on Terrorism and Irregular Warfare

SPONSORED PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Defense Analysis is provided below.
Size of Program: $2.1M
<table>
<thead>
<tr>
<th>Name</th>
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DEFENSE ANALYSIS

DISCRETE COMBAT MODELS AND LANCHESTER EQUATIONS
William P. Fox, Professor
Department of Defense Analysis
Sponsor: Unfunded

OBJECTIVE: To find analytical solutions, where applicable, and to discover relationships between variables, constants, and solutions to aid in analysis.

SUMMARY: The principal investigator (PI) was able to solve the discrete “direct fire” equations and find many valuable relationships using Eigenvalues and Eigenvectors that relate directly to the parameters of the model. The PI prepared a paper for an IJORIS journal. The article is being revised per reviewer’s comments. The physics lab at John’s Hopkins University is using the PI’s model to help in their modeling effort.

EARLY DIAGNOSIS OF HEPATITIS IN POTENTIAL TISSUE DONORS
William P. Fox, Professor
Department of Defense Analysis
H. Thomas Temple, Department of Orthopedics
Bill Buck, Department of Orthopedics
University of Miami School of Medicine
Sponsor: Unfunded

OBJECTIVE: To determine how to prevent hepatitis in the transfer of tissue during surgery

SUMMARY: Transplantation of tissues has to be done in the safest manner possible, avoiding, at all costs, the transmission of communicable diseases from the donor to the multiple recipients of the donor’s tissues. One such communicable disease is hepatitis. Blood tests are used to identify donors who may have hepatitis in an effort to eliminate them from the donor pool.

The significance of a positive blood test for the “Hepatitis B core antibody” (HBcAb) – in the process of approving, or not approving, donors for transplantation – has remained controversial for many years. This controversy centers around whether individuals who are positive for HBcAb (HBcAb+) (and who are negative for all other hepatitis serologic markers) can be regarded as “completely cured” (therefore, safe as donors) or as having a “low clinical level of disease” (therefore, not safe as donors).

Since hepatitis also induces changes in the liver that can be identified under a microscope, liver sections from autopsies of HBcAb+ donors have been microscopically examined and compared to similar sections from negative donors (HBcAb-).

Several factors complicate the analysis, however, including the presence of other diseases that affect the liver, most prominently diabetes, ethanol use, and medication or drug use.

The selected “readout” morphologic categories (dependent variables) are “Stage,” “Portal grade,” and “Lobular grade.” Each of these categories have received scores from 0 to 4 (0 = normal, 1–3 = progressive liver involvement with 3 and 4 as severely involved).

The categories of Necrosis, Plasma Cells, Binucleation, Steatosis, Mallory’s hyaline, and Glycogen are histological details. The first three should correlate with stage. Steatosis, and possibly Glycogen, should correlate with diabetes, and Mallory’s hyaline should correlate with ethanol abuse.

It is believed that the way to proceed could be:

1. First, see if there are significant differences in the readout results between those who are HBcAb+ and those who are HBcAb-. It is anticipated that the result will be “no significant difference.”

2. Next, exclude those with “other significant disease” and see if there is a significant difference again between HBcAb+ and HBcAb-. It is anticipated that there will be a difference.

3. If there is “no significant difference,” then try to combine the higher scores in the two grades into one single score, as is customary among pathologists.

4. Next, try to see if those who are HBcAb+ and HbsAb+ differ from those who are HBcAb+ and HbsAb-, (HbsAb indicates Hepatitis B surface antibody). The literature suggests that this result will be negative.
DEFENSE ANALYSIS

This is a two year project leading to publications and presentation at medical conferences.

THE ECONOMIC IMPACT OF TERRORIST ACTIVITIES AND NATURAL DISASTERS
William P. Fox, Professor
Gordon H. McCormick, Professor
Department of Defense Analysis
Sponsor: RIP

OBJECTIVE: To find interrelationships between terrorist activities and/or natural disasters and economics, including but not isolated by stock market activities.

SUMMARY: Preliminary dynamic models were built. Software was purchased and learned data is still required. The form of the model will be a dynamical system’s model. Funding proposals were sent to Professor Sepp in Washington, D.C.

FUNGATING TUMORS ANALYSIS
William P. Fox, Professor
Department of Defense Analysis
H. Thomas Temple, Department of Orthopedics
University of Miami School of Medicine
Sponsor: Unfunded

OBJECTIVE: To look at malignant tumors of soft tissue that are advanced and actually erode through the skin at the time of presentation.

SUMMARY: The principal investigators (PIs) looked at two groups of patients: patients with “fungating tumors” and a cohort without any skin breakthrough. The PIs looked for any distinguishing and statistically significant differences between these two groups. Specifically, these were modeled in regard to a difference with regard to age, location, size, or depth. More importantly, the PIs looked at a difference between local recurrence and survival.

The following were found to be statistically significant.

- Stage and fungating (p=0.028)
- Survival and fungating (p=0.002)
- Mets and fungating (p=0.011)
- Age and fungating (p=0.029)
- Grade and fungating (p=0.035)

The results will be submitted as an abstract at the American Academy of Orthopaedic Surgeons Meeting next year and the PIs are working on the manuscript.

A MATHEMATICAL MODEL FOR BONE AND TISSUE DONORS
William P. Fox, Professor
Department of Defense Analysis
H. Thomas Temple, Department of Orthopedics
University of Miami School of Medicine
Sponsor: Unfunded

OBJECTIVE: To build a mathematical model that bone and tissue banks can use to determine the quality of potential donors.

SUMMARY: The principal investigators are currently evaluating the data provided.
DEFENSE ANALYSIS

MULTI-SENSOR DETECTION OF SHIPS IN COASTAL REGIONS
William P. Fox, Professor
Department of Defense Analysis
John Vesecky, UCSC
Sponsor: Submitted to NSI

OBJECTIVE: To improve maritime situational awareness in coastal regions.

SUMMARY: The proposal is being finalized and submitted.

SENSING AND IDENTIFYING PERSONS AND/OR ANIMALS CARRYING WIRES ON THEIR PERSONS
William P. Fox, Professor
Department of Defense Analysis
John Vesecky, University of California-Santa Cruz
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To build mathematical models and a simulation to test baseline radar and sensing devices to detect wires on persons/animals in crowds.

SUMMARY: The proposal was submitted last July and just approved for work.

SYSTEM MODELING OF U.S. EFFORTS AS APPLIED TO THE WAR ON TERROR IN IRAQ AND IRAQ’S INFRASTRUCTURE RESILIENCY
William P. Fox, Professor
Department of Defense Analysis
Sponsor: RTO

OBJECTIVE: To build a formal model or models for the Three Rings of the Iraq War. (Note: This research is part of the RRTO-sponsored project “Countering Insurgent Violence: Winning in Iraq, Understanding the Dynamics of Contemporary War.”)

SUMMARY: Part I. Modeling the War on Terror. Problem Identification: Determine the proper strategies that the United States and non-state actors (NSA) should employ in order to accomplish each players’ goals/objectives.

Results from Game Theory Analysis: There is a pure Nash Equilibrium at U.S. Strategies to strike militarily and the NSA strategy is to support terrorism. The values used in this game theory model are not as important as their relative ordering. Provided the ordering is the same, then the result will still be a pure Nash Equilibrium. The U.S.-Iraq conflict followed this result.

The position that the US favors is “do not strike militarily,” perhaps in favor of a diplomatic or political strategy. However, this strategy appears to be unattainable under normal conditions. The U.S. might consider strategic moves (such as threats, promises, combinations of threats and promises, negotiations, etc.) in order to get the key players (the U.S. and the NSA) to move toward non-violent strategies. There are no stable strategies in this game. Since we are involved in this military (U.S.) and violent (NSA) strategy, we need to build a more fluid model to determine how we are doing and how we can react to terrorist activities. However, this part of the modeling shows how we initially got into the conflict with Iraq.

Even as we add more strategies, the military-violence strategy is the pure Nash Equilibrium. This is not the strategy of choice, but may be the strategy of necessity. The U.S. would like to find viable methodologies to allow alternate strategies to prevail. Given that, the model suggests military intervention.

Part II. Problem Identification: Build a mathematical model that relates infrastructures dynamics to shock effects of “war” activities. Consider “war” activities to be terrorist acts, insurgency operations, and civil war activity.
**Issues:** How to model the infrastructure of a metropolitan area or country so as to better understand “resilience” with respect to major system shocks? The shocks can be insurgency operations, terrorist activity, or civil war violence. What is an appropriate balance between preparedness and responsiveness investments for strategic planning? How to capture the loss in productivity imposed by response plan implementation?

Five different scenarios were run to evaluate the effectiveness of the model. The last scenario was rerun using stochastic parameters and simulated for 1,000 trials in obtaining the analysis of the model.

**RELIGIOUSLY MOTIVATED VIOLENCE: WHERE DOES IT COME FROM?**
**CAN IT BE DETERRED?**
Heather S. Gregg, Assistant Professor
Department of Defense Analysis
Sponsor: Naval Postgraduate School

**OBJECTIVE:** This research will have two components. First, it will consider the different ways in which religion fuels violent behavior, ranging from religious-based ethics for using force to “cosmic war,” in which violence becomes a sacred duty in defense of the faith. Second, it will investigate the effects of kinetic operations—especially two major wars—on an ideology that claims Islam is under attack, and it will consider ways we can fight the global war on terrorism and de-legitimize Al Qaeda’s ideology.

**THE CORE LAB RESEARCH PROGRAM**
Nancy C. Roberts, Professor
Douglas A. Borer, Associate Professor
Kristen Tsolis, Research Associate Professor and CORE Lab Supervisor
Department of Defense Analysis
Sponsor: Office of the Under Secretary of Defense/Rapid Reaction Technology Office

**OBJECTIVE:** To leverage analytical technologies to educate the officer corps on how to apply theoretical concepts to the problems of terrorism and irregular warfare.

**SUMMARY:** The CORE Lab at the Naval Postgraduate School has a threefold mission to support field operatives engaged in irregular warfare.

The CORE Lab develops operators’ knowledge, skills, and abilities in visual analytics. Three visual analytic methodologies are emphasized in courses and research projects: geospatial analysis, temporal analysis, and relational analysis. The application of these methodologies, and the analytical software tools associated with them, enables operators to collect, manage, and fuse data in order to create a more complete picture of the common operational environment.

Based on a more nuanced understanding of the environment, operators are challenged to develop a range of strategies for in-country interventions. Alternative counter-insurgency strategies include direct action approaches (e.g., counter-terrorism campaigns and man-hunting missions); indirect action strategies (e.g., IO and psyops campaigns); and conflict-resolution/post-conflict reconstruction strategies (e.g., interagency-coordinated civil-affairs programs).

Through an exploration of data integration techniques and an examination of alternative strategies for action, the CORE Lab serves as the center of gravity for teaching and research on military fusion cells at the operational level. The human capital developed informs and enhances fusion cell operations and effectiveness.

**PUBLICATIONS:**


**BOOK:**


**CONTRIBUTIONS TO BOOKS:**


**NAVAL POSTGRADUATE SCHOOL FULL-SPECTRUM SYSTEMS ANALYSIS FOR COUNTERING INSURGENT VIOLENCE**

*Hy S. Rothstein, Senior Lecturer*
*Heather S. Gregg, Assistant Professor*
*John Arquilla, Professor*
*Department of Defense Analysis*

**Sponsor:** Rapid Response and Technology Office, Office of the Secretary of Defense

**OBJECTIVE:** To collect and analyze data on Iraq; and to develop counters to selected current and projected insurgencies. This effort will conduct a full-spectrum systems analysis of systems and subsystems that produce the violence. These systems must be understood before they can be countered. This effort will begin with an analysis of the social, political, economic, and military networks that affect terrorist decision-making. The project will identify insurgencies, attempt to anticipate future modes of irregular warfare, and estimate their level of danger. The project’s recommendations may be operational, technical, doctrinal, budgetary, and policy-related.

An understanding of this problem recognizes that the critical issue is the insurgency, not the insurgents’ weapons, which may be explosive devices today, but may change to alternate threats in a short time-frame. Insurgencies are violent political struggles. It is the underlying systems that cause and sustain the violence that must first be understood.

**IRREGULAR WARFARE AND ANTHROPOLOGY: CASE STUDY INDIA**

*Anna Simons, Professor*
*Department of Defense Analysis*

**Sponsor:** Office of the Secretary of Defense-Policy Planning

**A LONG-TERM STRATEGY SEMINAR: REGIONAL STABILIZATION**

*Anna Simons, Professor*
*Department of Defense Analysis*

**Sponsor:** Office of the Secretary of Defense-Office of Net Assessment
DEFENSE ANALYSIS

OPERATIONAL PLANNING IN MARITIME TERRORIST ATTACKS
David C. Tucker, Associate Professor
Michael E. Freeman, Assistant Professor
Department of Defense Analysis
Sponsor: Office of Naval Intelligence

OBJECTIVE: To identify any “critical pathways” in the operational planning of maritime and other terrorist attacks that will allow analysts to track developing attacks.

SUMMARY: The first phase of the research identified a general pattern in a set of maritime terrorist attacks. The second phase (FY08) sought to refine this pattern and to see if it is generally valid by examining several different sets of terrorist attacks. The research concluded that a general pattern was discernible, but nothing that could be identified as “critical pathways.”

PUBLICATION:

BOOK:
DEFENSE ANALYSIS

PUBLICATIONS


Fox, W., “Contest Director’s Article,” Consortium, No. (94), Spring/Summer 2008.


CONFERENCE PUBLICATION


PRESENTATIONS


Fox, W.P., “Mathematical Modeling, the Mathematical Contest in Modeling (MCM) and the HIMCM,” Joint Mathematics Meetings, San Diego, California, 6 January 2008.

Fox, W.P., “Preparing Liberal Arts Faculty to Teach Modeling and Problem Solving at the College Algebra Level at FMU,” Joint Mathematics Meetings, San Diego, California, 6 January 2008.

Freeman, M., presentations/briefings to the Iraqi Counter-Terrorism Bureau and Counter-Terrorism Brigade, Baghdad, February 2008.

Freeman, M., presentations/briefings to the Navy SEALs, Coronado, California, June 2008.


Gregg, H.S., “Introduction to Islam, Ethnic Antagonisms in the Middle East, Cultural Awareness in the Middle East, Iraq’s Insurgencies,” USS LINCOLN, 17-26 March 2008.

Gregg, H.S., “Introduction to Islam, Ethnic Antagonisms in the Middle East, Cultural Awareness in the Middle East, Iraq’s Insurgencies, Islamic Fundamentalism, Regional Implications for the 2006 War in Lebanon,” USS THEODORE ROOSEVELT, 7-18 September 2008.


DEFENSE ANALYSIS

BOOKS


CONTRIBUTIONS TO BOOKS


DEFENSE ANALYSIS


CONGRESSIONAL TESTIMONY


REPORTS


DEPARTMENT OF
INFORMATION SCIENCES

DANIEL C. BOGER
CHAIR
OVERVIEW:

The Department of Information Sciences (IS) 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 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 Information Warfare Systems Engineering
- Master of Science in Systems Technology
- Master of Science in Electronic Warfare Systems Engineering

RESEARCH THRUSTS:

- Military Experimental Design, Data Collection, and Analysis
- Field Experimentation and CONOPS of Information Systems
- 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 Battle Laboratories (STBL): The Naval Postgraduate School’s systems technology battle 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 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 the Defense Advanced Research Projects Agency (DARPA) Leading Edge Services ATM network, the California Research and Education Net (CALREN), the 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.

NPS’ systems technology laboratories contain (or have distributed access to) actual command-and-control systems for exercises and experiments. The prime example 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 well as selection, dissemination, and monitoring of execution. The STBL routinely conducts experiments with humans in the loop. Operational teams of officer students can be trained and 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, speeding the acceptance of new approaches to decision-making and training.

RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Information Sciences is provided below.

Size of Program: $10M
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</tbody>
</table>
THE JOINT MULTI-MISSION ELECTRO-OPTIC SYSTEM
William David Place, Research Associate
Department of Information Sciences
Sponsor:

SUMMARY: The principal investigator (PI) is a major contributor to the Joint Multi-Mission Electro-Optic System (JMMES) Project (a three-year plus, $650K plus, Naval Postgraduate School (NPS) initiative). JMMES is an FY07 to FY10 Joint Capabilities Technology Demonstration with the primary objective to assess and transition an automated processing and targeting capability that will support joint coalition and interagency wide-area surveillance. Commander, Third Fleet, is designated as the operational manager (OM) for the JMMES project, which entails coordination with the program manager to ensure that the primary goal of enabling multiple ISR missions, through the development and testing of a common turreted sensor suite, is realized. NPS provides the expertise necessary to perform OM duties through research, development, testing, and analysis of the JMMES sensor suite.

NAVAIR PMA-263 – UNMANNED AIRCRAFT SYSTEMS (UAS) SUPPORT TO COMMANDER, THIRD FLEET STAFF TASK
William David Place, Research Associate
Department of Information Sciences
Sponsor:

SUMMARY: The principal investigator (PI) completed his second year as a Naval Postgraduate School Research Associate, on assignment to Commander, Third Fleet (C3F), San Diego, California. The PI served as a Technical Advisor to the Third Fleet Commander, VADM Sam Locklear, and effectively conducted interactions with unmanned aircraft systems (UAS) organizations in government, academia, and industry. The PI assisted and advised the Commander and staff regarding requirements that will have a critical impact on fleet operational capabilities; and also supported the Department of Navy (DoN) S&T and R&D communities, providing recommendations for rapid technology insertions and long-term investments.
Conference Participation

Place, W.D., Armed Forces Communications and Electronics Association Symposium, February 2008.


Place, W.D., AUVSI Board of Directors Meeting, December 2008.

Place, W.D., JMMES CONOPS and Assessment Working Group, April 2008.


Place, W.D., JMMES Program Management Review with OSD Representative, December 2008.


Place, W.D., Navy UAS Working Group, March 2008.

Place, W.D., Non-Acoustic ASW Experiment, Initial Planning Conference, August 2008.

Place, W.D., Non-Acoustic ASW Experiment, Main Planning Conference, October 2008.

Place, W.D., RIMPAC 08 Final Planning Conference, March 2008.

Place, W.D., UAS Payload Conference, November 2008.

Place, W.D., USS OSCAR AUSTIN Post-Deployment Conference, August 2008.

Presentations

Place, W.D., “Fleet UAS Requirements,” Brief to NAVAIR Technical Manager for JMMES, August 2008.


Place, W.D., “Fleet UAS Requirements,” Brief to Representatives from the Rand Institute, February 2008.

Place, W.D., Provided Several Briefs to C3F Staff, with Overviews of New UAS Technologies/Capabilities and Recommendations Regarding a Way-Ahead for the Employment of all UAS Programs of Record.

Place, W.D., “STUAS (Small Tactical UAS),” Operational Requirements Brief to Raytheon Team, February 2008.
DEPARTMENT OF OPERATIONS RESEARCH

KEVIN R. WOOD
AND
ROBERT F. DELL
CHAIRS
OVERVIEW:

The Naval Postgraduate School’s 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 their final decisions. Operations research offers a scientific approach to the decision-making process through an array of mathematical, probabilistic, and statistical techniques.

The military uses OR at the strategic, operational, and tactical levels for such activities as 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’s 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 its 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 the Department of Defense (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 Mathematics)
- 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
- Master of Systems Analysis
- Master of Science in Human Systems Integration
- Doctor of Philosophy
OPERATIONS RESEARCH

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)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. 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: 4.3M
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OBJECTIVE: To identify the primary drivers of system structure and function in terms of well-defined optimization problems. To elucidate a theory of robustness and fragility of networks and network topology in connection to network behavior and function and optimization, with emphasis on the role of duality, game theory, and layering.

This research is part of a Multi University Research Initiative (MURI) Award, with colleagues at the University of Pennsylvania, the California Institute of Technology, the University of California-Santa Barbara, and the University of California-San Diego. The overall objective of the team is to clarify and address the central research challenges of network-centric complex systems: understanding network structure and function, domain-specific drivers and constraints, and the crucial issue of network architecture. The research team is working to develop and implement a broad-based, cross-disciplinary, research program focused on rigorous, scalable, and provably correct analysis of networks and network data.

SUMMARY: The popular, simple, graph-theoretic abstraction of a network as just nodes and edges with random wirings and interconnections, without details of form, dynamics, functionality, and context, can be seriously misleading, particularly when components are themselves complex dynamical systems or human actors. To date, considerable effort has been spent contrasting the tools and techniques of recently popular “network science” to the views of operations research and engineering, with particular emphasis on the Internet. The key idea in this approach is that the structure of a complex network is fundamentally tied to its function, and so any effort to model such a network must capture both its structural and functional elements. In particular, it is believed that the structure of complex networks is not arbitrary or random, but is organized to manage tradeoffs between what is feasible and what is desirable. The mathematical language that naturally reflects this decision process is constrained optimization. Optimization-based models for optimal routing, provisioning, and design of Internet Protocol (IP)-based networks have been developed. The research team is also working to develop a unified theory of network architecture that articulates the organizational principle behind the structure of various types of networks.

PUBLICATIONS:


PRESENTATIONS:


THESES DIRECTED:


KEYWORDS: Network Science, Complex Network, Internet Topology, Network Architecture, Reverse Engineering, Robust Yet Fragile

OPTIMIZATION-BASED REVERSE ENGINEERING OF THE ROUTER-LEVEL INTERNET INFRASTRUCTURE

David L. Alderson, Assistant Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To obtain a comprehensive picture of the existing router-level Internet infrastructure and its drivers, while also developing the appropriate mathematical framework and modeling tools to investigate “what-if” scenarios related to changes in the objectives, constraints, and tradeoffs affecting future networks. The products of this research will facilitate a more realistic and detailed vulnerability assessment of existing router-level Internet infrastructure at the regional and national scales, while also suggesting new strategies for their protection and future design.

SUMMARY: A collection of optimization-based models for routing, provisioning, and traffic engineering in both wired and wireless Internet Protocol (IP)-based networks was developed. These models consider the strategic and operational decisions of a “network operator” who must make tradeoffs between what is desirable in terms of network performance and what is feasible based on existing technologies and resources. For wired IP networks, the decision-maker is typically an Internet service provider (ISP), civilian or military, who owns and operates the network. Wireless networks are most prevalent in the
presence of field operations or humanitarian assistance and disaster relief operations. These models leverage existing “attacker-defender” mathematics developed by Naval Postgraduate School–Operations Research colleagues to assess the worst-case disruption to a network from an intelligent adversary.

**PUBLICATION:**


**PRESENTATIONS:**


**THESES DIRECTED:**


**KEYWORDS:** Optimization-Based Reverse Engineering, Traffic Engineering, Network Provisioning, Topology Design, Attacker-Defender, Internet Topology, Wireless Mesh Network
COUNTER-IMPROVISED EXPLOSIVE DEVICES RESEARCH

Gordon H. Bradley, Professor
Robert A. Koyak, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To support research and education on countering improvised explosive devices (IEDs). Statistical models for the incidence of IED events and the risks associated with them will be developed, taking into account the movement of Blue-force vehicles on road networks. The Naval Postgraduate School (NPS) SIGACTS Viewer will be used for other analysis. A model based on Living Systems Theory will be developed to model insurgencies and their IED systems.

SUMMARY: There is broad understanding that statistical tools are needed to better understand the dynamics of IED emplacements on road networks. At a given location these emplacements are affected by a number of factors, including the movement of Blue-force vehicles. The research team developed statistical models based on survival analysis and counting processes that take these factors into account. The findings were described in a white paper (supported jointly by the Joint IED Defeat Organization (JIEDDO)) that was delivered in September 2008. The research team also analyzed the effectiveness of UAVs in detecting IEDs in Iraq by estimating the false-detection ratio of IEDs by UAVs. The NPS SIGACTS Viewer was augmented to support this analysis. The Viewer was further modified to provide search for given words and phrases in the description of IED events to support detailed analysis of IED incidents in Iraq. A Living Systems Model of insurgency was developed and the effectiveness of the model was demonstrated by applying it to the Sunni insurgency in Iraq.

PRESENTATIONS:


TECHNICAL REPORTS:


SOFTWARE:

Naval Postgraduate School SIGACTS Viewer.

THESIS DIRECTED:

KEYWORDS: Improvised Explosive Devices, Route Clearance, Survival Analysis, Counting Processes, Censoring

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: To develop and implement: 1) “global Benders decomposition” for solving bilevel and trilevel optimization models arising in such problems as network interdiction and defense of critical infrastructure, and 2) the Naval Postgraduate School (NPS) SIGACTS Viewer to dynamically display and analyze incident data from Operation Iraqi Freedom, and further develop and distribute the Network and Graph Markup Language (NaGML).

SUMMARY: The principal investigators (PIs) described an implemented global Benders decomposition with an application to the optimal attack of a large-scale electrical-power grid. The decomposition did not require convexity of the underlying problem and should have applications in many areas. The PIs developed a unified, general framework of insurgency based on James Grier Miller’s Living Systems. The framework’s effectiveness was demonstrated by applying it to the Iraq Sunni insurgency. The NPS SIGACTS Viewer was augmented to support improvised explosive device (IED) analysis in Iraq and Afghanistan. The viewer was further modified to provide search for given words and phrases in the description of IED events.

PUBLICATIONS:


**PRESENTATIONS:**


CONTRIBUTION TO BOOK:


THESIS DIRECTED:


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

OBJECTIVE: To develop and implement trilevel optimization models—each is a “defender-attacker-defender model,” which is a type of Stackelberg game—with military and homeland-defense applications.

SUMMARY: A three-stage Stackelberg game for optimal hardening of critical infrastructure and other applications was described: a) the defender of a system uses limited resources to harden certain system components, i.e., to make those components resistant or invulnerable to attack; b) an attacker observes these defensive preparations and “interdicts” some components, reducing their usefulness to the defender; and c) the defender, as system operator, operates the interdicted system optimally. Typically, system operation is modeled as a linear program. The defender’s overarching goal is to minimize the worst possible damage that the attacker can inflict, when measured through the cost of post-interdiction system operation. This paradigm was applied to bio-defense, and a variant was applied to anti-submarine warfare (ASW) mission planning. In this variant, the inner attacker-defender model forms a two-person zero-sum game: a) in the first level, the defender assigns missions to “visible” (detectable) ASW missions to protect a high-value unit (e.g., an aircraft carrier), and b) in the second two levels, the attacker and defender engage
in a game that probabilistically routes attacking submarines and “secret” defensive platforms. The secret platforms use passive sonar and the attacker is unlikely to detect them.

**PUBLICATIONS:**


**PRESENTATIONS:**


CONTRIBUTION TO BOOK:

THESES DIRECTED:


KEYWORDS: Integer Programming, Stochastic Programming, Bilevel Programming, Dynamic Planning, Network Optimization, Network Interdiction

OPTIMAL MIX, DEPLOYMENT, AND OPERATION OF SENSORS IN AN URBAN AREA
CDR Douglas Burton, USN, Military Faculty
Moshe Kress, Professor
Kyle Lin, Associate Professor
Roberto Szechtman, Assistant Professor
Department of Operations Research
Sponsor: Multi-National Force Corp Iraq

OBJECTIVE: To develop a tool that can be used to perform persistent surveillance in an urban environment.

SUMMARY: G-3 S&T requires operational analysis to support fielding and operation of current and future persistent-surveillance technologies. In response to this need, an operational-level decision aid was developed to effectively detect and track people or groups of people of interest and to inform decisions regarding system procurement and apportionment.

PUBLICATION:

KEYWORDS: Sensor Employment, Persistent Surveillance, Poisson Process

EDUCATIONAL AND ANALYTICAL SUPPORT TO THE NATIONAL ASSESSMENT GROUP
Samuel Buttrey, Associate Professor
Thomas W. Lucas, Associate Professor
COL Andy Hernandez, United States Army
Department of Operations Research
Sponsor: National Assessment Group, Office of Secretary of Defense

OBJECTIVE: To provide the National Assessment Group (NAG) with periodic short-courses in state-of-the-market techniques in operations research; and to offer reach-back capabilities for short- and long-term studies. The goals of this effort are to stimulate and advance the knowledge of NAG personnel to be the nation’s premier independent assessment organization for important programs in support of immediate and critical mission priorities for the Department of Defense and other Executive Branch agencies; to prepare for future requirements through the long-term study of emerging conventional and irregular threats, technologies, and social and economic upheavals; and to establish reach-back capabilities for NAG missions that require specialized and immediate attention.

SUMMARY: From April 2007 to September 2008, the Naval Postgraduate School (NPS) research team offered education and research support to the NAG. Along with NAG leadership, the team developed a one-year program of relevant short-courses. Each course supported fundamental needs in the studies that the NAG performs. The education team outlined at least one short-course for each fiscal quarter. The team prepared for times that the NAG required support to conduct studies that needed special tools and special techniques to provide valid reports. The team traveled to Kirtland Air Force Base, Albuquerque, New Mexico. They provided NAG analysts and study leads courses in bootstrap techniques and data analysis. The team used R software and left residual capabilities to the NAG for future use. Study material and briefing material were also delivered to the sponsor. A long-term goal of this effort is to establish a
partnership between the NAG and NPS. A working plan is to connect experience/thesis students with NAG issues.

PRESENTATION:


THE CNO DISTINGUISHED FELLOWS PROGRAM: A CRITICAL INFRASTRUCTURE WORKSHOP
W. Matthew Carlyle, Associate Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To hold a workshop on current research in critical-infrastructure vulnerability analysis.

SUMMARY: The workshop was held from 13-15 August 2008 at the Naval Postgraduate School (NPS), with 26 faculty members in attendance, including 13 faculty members from outside NPS. Leon Panetta provided a plenary talk on infrastructure. Attendees presented their own research and discussed alternate approaches to determining the vulnerability of critical infrastructure.

PRESENTATION:


KEYWORDS: Linear Programming, Integer Programming, Network Optimization, Network Interdiction, Critical Infrastructure, Vulnerability Analysis, Risk Analysis

THE MILITARY APPLICATIONS OF OPTIMIZATION
W. Matthew Carlyle, Associate Professor
David L. Alderson, Assistant Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To develop optimization models, algorithms, and automated decision aids for military applications.

SUMMARY: Models and decision aids were developed for: the optimal daily assignment of each ship in a fleet of U.S. Navy ships to (multiple) missions; optimal sensor and munitions package selection and mission assignment for unmanned aircraft systems; optimal allocation of resources to support competing classes of computer network traffic; optimal deployment of wireless networks to support humanitarian assistance and disaster relief; optimal placement and management of sensor networks for border security; and optimizing roadblock and sensor positioning to locate and capture fleeing nuclear-materials smugglers in a road network.

PUBLICATION:

PRESENTATIONS:


THESES DIRECTED:


KEYWORDS: Linear Programming, Integer Programming, Dynamic Planning, Network Optimization, Network Interdiction

SEALIFT CAPABILITY: SIZE, COMPOSITION, AND EMPLOYMENT

W. Matthew Carlyle, Associate Professor
Gerald G. Brown, Distinguished Professor
Department of Operations Research
Sponsor: Naval Surface Warfare Command-Carderock Division

OBJECTIVE: To develop optimization models, algorithms, and automated decision aids for assessing U.S. Navy sealift capability.

SUMMARY: An optimization-based decision-support system for combat logistics force (CLF) assessment was extended and improved. These changes were documented in various theses and publications. The model schedules a fleet of CLF shuttle ships to serve the logistical needs of a list of client battle groups over a finite time horizon (i.e., 15 up to 180 days), at daily resolution, so as to minimize shortages of four basic commodities.

PUBLICATION:

KEYWORDS: Linear Programming, Integer Programming, Dynamic Planning, Network Optimization, Scheduling, Logistics

BASE REALIGNMENT AND CLOSURE INFRASTRUCTURE ANALYSIS
Robert F. Dell, Professor
Department of Operations Research
Sponsor: Army Assistant Chief of Staff for Installation Management

OBJECTIVE: To work on a book describing the analysis used by the Army for the 2005 round of base realignment and closure.

SUMMARY: The investigator has worked and written extensively on base realignment and closure (BRAC). This research supported work on a book describing the analysis used by the Army for the 2005 round of BRAC. The soon-to-be-completed book is a collection of lessons learned, as well as a discussion on how such analysis can be improved. The book is expected to become a seminal reference for future BRAC.

PUBLICATION:

PRESENTATIONS:


KEYWORDS: BRAC, Capital Budgeting, Optimization, Decision Analysis, Integer Linear Programming Application

CENTER FOR ARMY ANALYSIS (CAA) ANALYTICAL SUPPORT
Robert F. Dell, Professor
Department of Operations Research
Sponsor: United States Army, Center for Army Analysis

OBJECTIVE: To provide analytical support to the Center for Army Analysis.

SUMMARY: The investigator helped develop an optimization model to plan non-combatant evacuation. The investigator and Major Steve Sparling won the 2008 Military Operations Research Society David Rist Prize based on this research. Details are classified.

PRESENTATION:

KEYWORDS: Integer Linear Programming Application, Non-Combatant Evacuation
OPTIMIZATION MODELS FOR INSTALLATION MANAGEMENT
Robert F. Dell, Professor
Department of Operations Research
Sponsor: Army Assistant Chief of Staff for Installation Management

OBJECTIVE: To develop optimization models to assist with installation management.

SUMMARY: The investigator provided research, support, and development of optimization models to assist the Army’s Assistant Chief of Staff for Installation Management. The integer-linear program BAEC (Budget Allocation for Environmental Cleanup) was the primary 2008 development effort. In 2008, the Army used BAEC to help plan over $400 million in environmental clean-up.

PUBLICATION:

PRESENTATIONS:


KEYWORDS: BRAC, Capital Budgeting, Optimization, Integer Linear Programming Application

A SHORT-COURSE ON SURVEY RESEARCH METHODS
Ronald D. Fricker, Jr., Associate Professor
Department of Operations Research
Sponsor: U.S. Marine Corps Operational Test and Evaluation Activity

OBJECTIVE: To provide Marine Corps analysts with a short-course on survey research methods. The course will give students a practical grounding in the important aspects of research survey methodology, from survey instrument design, to sample design, to modes of data collection, to methods for survey data analysis. The course will cover principles for conducting rigorous survey research and provide students with guidance for making successful decisions in the design and execution of high-quality surveys.

SUMMARY: A short-course was provided on-site at Quantico, Virginia, from 8-14 May 2008.

KEYWORDS: Survey Research, Short Course

STATISTICAL MODELS FOR FORECASTING INSURGENT STRIKES
Ronald D. Fricker, Jr., Associate Professor
Roberto Szechtman, Assistant Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To develop spatio-temporal models for improvised explosive device (IED) prediction; and to apply them to real IED data assembled from the fusion of information from diverse sources. The goal is to develop methods that formally and appropriately incorporate relevant spatial and temporal information into a predictive model in order to provide a probabilistic assessment of the likelihood of future attack within a particular region over a period of time.
SUMMARY: Research was conducted into various approaches to spatio-temporal modeling of point events, as well as methods for detecting changes in temporal and spatio-temporal distribution of events. In discussions with Joint IED Defeat Organization (JIEDDO) representatives, event prediction was of less interest, while modeling other aspects of the phenomenon that have the potential to provide insight into changes in the battlefield landscape was of more interest. Thus, research in 2008 concentrated on developing and evaluating temporal and spatio-temporal change-point detection methods. Biosurveillance data was used to facilitate publication, though methods apply directly to the IED problem. JIEDDO representatives were briefed on 7 January 2008. An ONR conference on “Research Directions in Information Integration” was hosted at the Naval Postgraduate School from 7-8 April 2008.

PUBLICATION:


PRESENTATIONS:


KEYWORDS: Temporal and Spatio-Temporal Modeling, Change Point Detection

CHARACTERIZING AND ANALYZING REQUIREMENTS FOR INTEGRATED MARITIME DOMAIN PROTECTION (MDP)

Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To evaluate numbers and types of assets needed to conduct maritime domain assurance and protection.

SUMMARY: Models were developed and exercised to evaluate numbers and types of assets needed to conduct maritime domain protection.

PUBLICATIONS:


**KEYWORDS:** Maritime Domain Awareness, Deterministic and Stochastic Models, Automatic Information System, AIS, Trusted Agent, Surveillance, Imperfect Classification

**REQUIREMENTS AND ASSESSMENTS, OPERATIONS RESEARCH/NETWORK MODELING**

Donald P. Gaver, Distinguished Professor  
Patricia A. Jacobs, Professor  
Department of Operations Research  
Sponsor: OPNAV, N61, N6132D

**OBJECTIVE:** To develop and study analytic and simulation models to assess the scalability of service-oriented architecture.

**SUMMARY:** Models for the interaction between consumers, producers, and a registry were proposed and studied.

**WORKING PAPERS:**


**KEYWORDS:** Service Oriented Architecture, Queuing, Decision Analysis, Modeling, Cloud Computing

**TRAINING AND RESEARCH SUPPORT FOR DOT&E**

Donald P. Gaver, Distinguished Professor  
Patricia A. Jacobs, Professor  
Department of Operations Research  
Sponsor: Director, Operational Test and Evaluation and the Naval Postgraduate School

**OBJECTIVE:** To develop training and reference materials and a new methodology for operational testing use emphasizing modeling and simulation.

**SUMMARY:** Models to study implementation of the policies to improve reliability of fielded systems were developed and studied.

**PRESENTATION:**


**WORKING PAPERS:**


TECHNICAL REPORT:


KEYWORDS: Military Test and Evaluation, Statistical Data Analysis, Decision Analysis, Modeling and Simulation

URBAN CULTURAL GEOGRAPHY IN STABILITY OPERATIONS
Patricia A. Jacobs, Professor
Donald P. Gaver, Distinguish Professor
Moshe Kress, Professor
Department of Operations Research
Sponsor: TRAC – Monterey

OBJECTIVE: To develop dynamic models focused on key intangible societal and cultural processes in the context of stability operations.

SUMMARY: In this study, mathematical descriptive models for representing entities, events, and processes in stability operations were developed. In particular, this research focused on the effect of military (“negative”) actions and civil-affairs (“positive”) actions on the population’s attitudes towards coalition forces and the insurgency, and on the persistence of these attitudes over time.

This project complemented the TRAC/TRISA project titled “Modeling the Dynamics of Insurgency and Counterinsurgency.”

THESIS DIRECTED:


KEYWORDS: Stability Operations, Dynamic Systems, Civil Affairs

MODELING THE VALUE OF INTELLIGENCE AND THE IMPACT OF COALITION FORCE ACTIVITIES IN COUNTER-IMPROVISED, EXPLOSIVE DEVICE OPERATIONS
Edward Kaplan, Professor
Yale University
Moshe Kress, Professor
Roberto Szechtman, Assistant Professor
Department of Operations Research
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To study tactical and operational problems related to counter-insurgency operations in the context of improvised, explosive device (IED) threats.

SUMMARY: Two problems were studied: one associated with the role of intelligence and insurgencies deployment tactics, the other concerned with IED attacks on convoys transporting supplies and troops. The first problem addressed the following questions: Under what conditions should government forces attack...
IED-producing insurgent strongholds? How should the government allocate its force across different strongholds? How should the government respond to “smart” insurgents who anticipate the government’s optimal plan of attack and prepare accordingly? The second problem explored the effect of various tactical parameters on IED and mortar-fire threats using probability and continuous-time Markov chain models.

PRESENTATIONS:


THESES DIRECTED:


KEYWORDS: Counterinsurgency, Intelligence, Force Allocation, Game Theory

THE DEVELOPMENT OF OPERATIONAL PLANNING TOOLS FOR THE MARITIME OPERATIONS CENTER

Jeffrey E. Kline, Senior Lecturer
Gerald G. Brown, Distinguished Professor
R. Kevin Wood, Professor
W. Matthew Carlyle, Associate Professor
Alan R. Washburn, Professor
Javier Salmeron, Associate Professor
Anton Rowe, Research Associate
Carol O’Neal, Research Associate
Regina Kaiser, Research Associate
John Looney, Military Faculty, Information Science

Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To develop and evaluate decision aids for use by Navy staffs to plan maritime operations. This research will produce, develop, evaluate, and deliver complete, operational prototypes of various optimization-based planning systems for supporting the Maritime Operations Center and Maritime Headquarters Planning Staff in maritime operational missions ranging from: strike; information, surveillance, and reconnaissance; theater security and cooperation; theater ballistic missile defense; anti-submarine warfare; logistics routing; transit planning; maritime interdiction operations; and others.

SUMMARY: In 2008, this program further advanced prototypic decision aids related to maritime operational-level planning. These included models for naval mission planning (Naval Mission Planner), combat logistics force planning (Combat Logistics Force Planner), area anti-submarine warfare planning (ASW Planner), and engagement mission planning from a sea base (CARMA). The Combat Logistics
Force Planner and CARMA were selected by the Naval Warfare Development Command and Commander, Second Fleet Staff, to be evaluated in a formal set of exercises in 2009. The Naval Underwater Warfare Center has requested further development of the ASW Planner for their suite of analytical tools.

**PUBLICATION:**


**PRESENTATION:**


**THESES DIRECTED OR SPONSORED:**


**GENERAL FACULTY SUPPORT TO NAVAL WARFARE DEVELOPMENT COMMAND TACTICAL DEVELOPMENT AND EVALUATION**

Jeffrey E. Kline, Senior Lecturer
Alan R. Washburn, Distinguished Professor Emeritus
Lyn R. Whitaker, Associate Professor
CAPT Douglas E. Otte, United States Navy
Department of Operations Research
Sponsor: Naval Warfare Development Command

**OBJECTIVE:** To provide “as tasked” analytical work to support the development of naval tactics. To provide ready funding at the Naval Postgraduate School for the Naval Warfare and Development Command’s Doctrine Division to task various faculty with aiding in tactical memorandum development and evaluation.

**SUMMARY:** This program supported data analysis of ship tracking error to help determine safe q-route width and distance in counter-mining operations. Other tactical programs supported included developing analysis to support tactical memorandums for torpedo employment and air defense.

**TECHNICAL REPORT:**

Tactical Memorandum (SECRET), Project 08-01.
THESES DIRECTED:


KEYWORDS: Tactics, Maritime Warfare, Antisubmarine Warfare

JOINT DEFENDER TEST AND EVALUATION
Jeffrey E. Kline, Senior Lecturer
Gerald G. Brown, Distinguished Professor
Department of Operations Research
Sponsor: Naval Warfare Development Command

OBJECTIVE: To resource the evaluation of Joint Defender, the Naval Postgraduate School-developed optimized-based decision aid for theater ballistic missile defense.

SUMMARY: This research supported the testing, evaluation, and modification of the operational prototype planning tool Joint Defender, an optimization-based system for locating platforms for theater ballistic missile defense. Joint Defender was evaluated in a Naval War College theater ballistic war-game and was used as an operational-level decision aid. Feedback concerning its performance was integrated into the game by the sponsor, the Naval Warfare Development Command.

KEYWORDS: Optimization, Planning, Theater Ballistic Missile Defense

THE MARITIME DEFENSE AND SECURITY RESEARCH MANAGEMENT ACCOUNT
Jeffrey E. Kline, Senior Lecturer
National Security Institute
Sponsor: Naval Postgraduate School Directed Research

OBJECTIVE: To conduct, coordinate, and collaborate maritime defense and security research, experimentation, and information-exchange between partnership universities; federal, state, and local agencies; national laboratories; the maritime industry; and international partners through the National Security Institute.

SUMMARY: The Maritime Defense and Security Research Program (MDSRP) underwrites several major field experimentations at the Naval Postgraduate School (NPS), including the maritime interdiction experimentation by Tactical Network Topology (TNT), COASTS, and SEA WEB. Other programs funded under this umbrella include the GSEAS maritime domain awareness work and environmental impact on sensors. In 2008, the MDSRP also initiated the Maritime Information Sharing Task Force (MIST). MIST, co-sponsored with the Department of Transportation, held its first local symposium at the Port of Long Beach to obtain information on policy barriers to information exchange between commercial entities and government agencies. This research also supports faculty labor and travel to attend various maritime homeland defense and security conferences or host them at the Naval Postgraduate School (NPS). This account also allows NPS to publish and distribute the monthly SITREP e-newsletter, which reports country-wide research initiatives related to maritime security.
PUBLICATIONS:


PRESENTATIONS:


TECHNICAL REPORTS:


THESES DIRECTED:


KEYWORDS: Maritime Security, Maritime Infrastructure
NAVAL OPERATIONS ANALYSIS TO SUPPORT NORTHROP GRUMMAN SHIP SYSTEM ANALYSIS

Jeffrey E. Kline, Senior Lecturer
John Vitalich, Lecturer
Regina Kaiser, Research Associate
Department of Operations Research
Sponsor: Northrop Grumman Ship Systems, Inc.

OBJECTIVE: To explore the use of analytical models, systems analysis, and warfare analysis to inform ship design.

SUMMARY: NGSB seeks to partner with the Naval Postgraduate School (NPS) to devise, build, develop, exercise, and assess a new analytical and modeling construct. NPS faculty expertise in independent defense-planning scenario generation, determination of critical performance parameters, and tactical- and mission-level mathematical modeling is considered instrumental to project success. Furthermore, in the course of their NPS curriculum, operations analysis students perform numerous short-term studies (including CONOPS development and concept development) and experimentation projects and must complete a research thesis. By their nature, many of these studies and projects can complement both contracted and independent MS&A research and development projects conducted at Northrop Grumman Shipbuilding, and are anticipated to provide innovative and provocative insights into evolving Navy and joint-service mission needs, operating concepts, and analysis methodology. NPS supported Northrop Grumman work in CY2008 by creating three defense guidance-like scenarios, generating tactical situations from those scenarios, and modeling them in Naval Simulation System.

KEYWORDS: Warfare Analysis, Tactical Analysis, Modeling

PREDICTING THE REMAINING USEFUL LIFE OF MECHANICAL COMPONENTS

Robert A. Koyak, Associate Professor
Department of Operations Research
Sponsor: Goodrich Corporation

OBJECTIVE: To develop statistical tools for use in predicting the remaining useful life of mechanical components in helicopters. This project provides travel and other support to CDR David Ruth in his Ph.D. thesis research on a related topic.

SUMMARY: Health and Usage Monitoring Systems (HUMS) are original equipment manufacture parts on utility helicopters (UH-60M/R/S, S-92, S-76d) and the F-35 Joint Strike Fighter. The requirement for HUMS is based on realizable improvements to safety and operational readiness. Additionally, it is hoped that there will be large cost benefits (reduction in logistics footprint and equipment maintenance cost) if data from HUMS can be used to predict the remaining useful life (RUL) of a component. Establishing the RUL of aircraft components will greatly affect logistics by allowing better selection of aircraft for mission; facilitating opportunistic maintenance, thereby reducing the occurrence of unscheduled maintenance; requiring fewer parts in inventory by allowing logisticians to better manage the supply chain; and moving aircraft maintenance of selected parts to an “on condition” practice, greatly reducing maintenance and operating cost of the aircraft.

Based on vibration-based data, parametric data, and aircraft maintenance records, techniques and algorithms were developed to estimate the RUL on components with a quantifiable bound-on-error (time remaining); identify aircraft components/systems that are out of tolerance and require maintenance; and correlate/evaluate physical component damage with vibration/strain-based condition indicators.

KEYWORDS: Reliability, Condition-Based Maintenance, Life Prediction, Change-Point Detection
EFFICIENT EMPLOYMENT OF REACTIVE SENSORS
Moshe Kress, Professor
Roberto Szechtman, Assistant Professor
Sponsor: GEE Funds

OBJECTIVE: To develop adaptive algorithms aimed at efficiently employing sensors that are subject to false-positive and false-negative errors.

SUMMARY: The principle investigators considered a sensor that is subject to false-positive and false-negative errors. The sensor searches for threat objects, such as ballistic missile launchers or improvised explosive devices. The objects are located in a certain area of interest, which is divided into area-cells. The area-cells are defined such that each one of them may contain at most one threat object. The task of the sensor is to determine if an area-cell contains a threat object; the objective of the searcher is to maximize the number of correctly determined area-cells. Since definitive identification of a threat object and subsequent handling of that threat are done by a limited number of available ground-combat units, the correct determination of an area-cell is crucial for better allocating and directing these scarce resources. An algorithm was developed, rooted in the theory of large deviations and stochastic approximation theory, which provably leads to the optimal allocation of search effort—allocation that maximizes the expected number of correctly determined area-cells—as the search budget becomes large.

PRESENTATION:


THESIS DIRECTED:


KEYWORDS: Sensor Employment, False Positive and False Negative Errors, Stochastic Approximation

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS: EXTENSIONS OF THE AERIAL SEARCH OPTIMIZATION MODEL
Moshe Kress, Professor
James O. Royset, Assistant Professor
Department of Operations Research
Sponsor: U.S. Special Operations Command

OBJECTIVE: To develop optimization models for the operation of unmanned aerial vehicles (UAV) and ground forces in special operations missions.

SUMMARY: Special operations missions increasingly make use of UAVs for reconnaissance, surveillance, and enhanced situational awareness. In this study, an optimization model that enables more effective deployment and employment of UAVs was constructed. Specifically, a situation where insurgents attempt to transit through a border area in order to carry out hostile activities inside friendly territory was considered. A small number of special operations teams with light reconnaissance vehicles (LRVs) and short-range, low-altitude, surveillance UAVs were assigned to search and detect enemy units transiting through the area. The optimization model prescribed optimal deployment locations for LRVs and optimal search patterns for UAVs. During this year, a dynamic model that complements the original static ASOM model was developed. The model was implemented into a decision support tool.
PUBLICATIONS:


PRESENTATION:


KEYWORDS: UAV, Special Operations, Optimization

MODELING THE DYNAMICS OF INSURGENCY AND COUNTERINSURGENCY

Moshe Kress, Professor
Roberto Szechtman, Assistant Professor
Department of Operations Research
Sponsor: TRADOC/TRAC/TRISA

OBJECTIVE: To develop dynamic models that capture intelligence and population-behavior effects in counterinsurgency situations.

SUMMARY: Developed descriptive, dynamic (differential equations) models that capture the effects of intelligence, collateral damage in the population (casualties in the population due to government poor targeting), and insurgents’ coercive actions on population behavior in general and on recruitment to the insurgency in particular. The resulting mathematical models revealed interesting insights regarding the dynamics of key state variables in an insurgency situation. In particular, this research showed why it is almost impossible to eradicate an insurgency by force. The idea of a “tipping point” in describing the effect of insurgents’ coercive actions was also introduced.

PUBLICATION:


PRESENTATIONS:


KEYWORDS: Counterinsurgency, Intelligence, Coercive Actions, Dynamic System, Lanchester Models

OPTIMIZATION OF SENSOR ALLOCATION FOR SEARCH AND SURVEILLANCE IN MARITIME, LITTORAL, AND URBAN ENVIRONMENTS
Moshe Kress, Professor
James O. Royset, Assistant Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To develop an operational and tactical decision aid for employing sensors in an area of interest and fusing the information obtained from these sensors and from other sources. The decision aid will be used to guide commanders and executive officers to efficiently operate sensors during surveillance missions and to effectively utilize the information obtained from these sensors. The decision aid will also help combat planners in developing concepts of operations for search and surveillance operations and support analysts in planning acquisition programs for sensors and platforms.

SUMMARY: The research team focused on sensors carried by unmanned aerial, ground, and surface vehicles, but also considered information from ground sensors, satellites, manned aircraft, and human-intelligence sources. The decision aid consists of two parts: a probability model for fusing information and an optimization model for operating the sensors.

PUBLICATIONS:


PRESENTATION:

THESIS DIRECTED:

KEYWORDS: Probability Map, Bayesian Update, Detection, Recognition, Interception, Optimization
ASSEMBLY OF SEA BASE ASSETS FROM GLOBALLY DISPERSED LOCATIONS
Kyle Lin, Associate Professor
Department of Operations Research
Sponsor: Chief of Naval Operations, Campaign Analysis and Modeling Branch

OBJECTIVE: To develop a mathematical model for the assembly of sea base assets from globally dispersed locations. To produce an optimal assembly plan based on data concerning mission locations, sea base assets, and mission requirements.

SUMMARY: The problem was formulated as a mixed integer program, with the goal to minimize an objective function that consists of three elements: total travel time of sea base assets, mission completion time, and penalties incurred for any unmet mission requirements. The output of the model included the destination of each sea base asset, arrival times, and other pertinent information. The model was implemented using Microsoft Excel for the user interface, data manipulation, and model generation; and using GAMS (General Algebraic Modeling System) for solving the mixed integer program.

KEYWORDS: Sea Base, Mixed Integer Programming

GAME-THEORETIC MODELS FOR JAMMING REMOTE-CONTROLLED, IMPROVISED, EXPLOSIVE DEVICES
Kyle Lin, Associate Professor
Department of Operations Research
Yu-Chu Shen, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School-Joint Improvised Explosive Device
Defeat Organization Research Program

OBJECTIVE: To use game-theoretic models to develop strategies on how to use jammers most effectively against radio-controlled, improvised, explosive devices (RCIEDs). Although the project focuses on strategies involving current technologies, the results will also provide insights on how the RCIED-jammer technologies are likely to evolve in the future.

SUMMARY: RCIEDs have been a major weapon choice of insurgents in Operation Iraqi Freedom since 2003. One effective way to prevent an RCIED attack is to use electronic jamming devices to interfere with the communication between a remote control and the RCIED itself. Due to communication and power constraints, however, the jammer often needs to select which radio frequencies to interfere with. This project developed a game-theoretic model to study this problem; the solution was implemented in a decision aid running in Microsoft Excel.

PRESENTATION:


KEYWORDS: Game Theory, Improvised Explosive Device, Probability Models
AGENT-BASED SIMULATION VERIFICATION, VALIDATION, AND ACCREDITATION
Thomas W. Lucas, Associate Professor
Gary E. Horne, Research Assistant Professor
Department of Operations Research
Sponsor: Northrop Grumman Ship Systems, Inc.

OBJECTIVE: To collaborate with Northrop Grumman (NG) on a study of agent-based simulation (ABS) verification, validation, and accreditation (VV&A).

SUMMARY: Agent-based simulations are increasingly being used in Department of Defense (DoD) studies—in particular, for investigations of irregular warfare (IW). There remain many issues about the VV&A process for such models. In this study, the Naval Postgraduate School (NPS) collaborated with NG to advise the Marine Corps on a VV&A framework for agent-based models. Specifically, the principal investigators pointed out that a software platform (like most ABSs, such as Pythagoras) cannot be validated (rather, its code is verified) since there is no control over the platform’s use. A validation toolkit should consist of tests to “prod” a model in an attempt to invalidate it. Finally, models that have not been or cannot be validated can still be useful; for example, as a tool for hypothesis generation or to assess the impacts of many assumptions.

CONFERENCE PUBLICATION:

KEYWORDS: Agent-Based Simulation, Design of Experiments, DOE, Simulation, Verification, Validation, and Accreditation, VV&A

AN ANALYSIS OF CAPABILITY REQUIREMENTS FOR FORCE PROTECTION OF MILITARY, AUXILIARY, AND COMMERCIAL VESSELS OPERATING IN A CONFINED AREA
Thomas W. Lucas, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To examine maritime force protection as part of The Technical Cooperation Program (TTCP).

SUMMARY: The Office of Naval Research (ONR) is participating in a study of maritime force protection as part of TTCP. TTCP is a “five-eyes” Defense Science and Technology Organization. The objective is to evaluate potential technology and tactics, techniques, and procedures solutions to guide future science and technology investments and, if applicable, to help guide tactics development. The scenario involved an Expeditionary Strike Group (ESG) conducting humanitarian relief operations in an area with known terrorists. A simulation was developed and thousands of computational experiments were run varying the capabilities and tactics of the ESG and the threat. An analysis of the results identified potential vulnerabilities and possible technical or tactical means to overcome them.

PUBLICATION:

KEYWORDS: Design of Experiments, DOE, Humanitarian Relief, Maritime Force Protection, Simulation, The Technical Cooperation Program
AN ANALYSIS OF CAPABILITIES OF RE-SUPPLYING T-AKES DURING A MILITARY CONTINGENCY IN THE ASIAN PACIFIC THEATER

Thomas W. Lucas, Associate Professor
Department of Operations Research
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To assess the port operations in Guam and the new T-AKE’s ability to re-supply in response to a military contingency in the Asian Pacific theater.

SUMMARY: This research explored the current and future capabilities of ordnance movements into the Asian Pacific theater. The use of simulation, logistics modeling, and data analysis identified critical factors and capabilities that are important to the effective movement of ordnance by Auxiliary Dry Cargo/Ammunition Ships (T-AKES) through Guam during a military contingency. The experimental design incorporated the effects of competing requirements on the ordnance re-supply process in Guam, specifically relating to the Department of Defense’s need to utilize the ordnance wharf for other tasks, as well as increased ordnance requirements. Results indicated that the inclusion of competing requirements to the system degrades both the T-AKE service level and the overall throughput of the system by nearly 25%. Analysis of critical factors contributing to this degradation indicated that the T-AKE arrival cycle was the largest contributing factor to the system’s effectiveness. The results also indicated that competition for the wharf and ordnance contributes to the effects on the system, but is never the most influential factor. Other insights into the system revealed that the decision of where to process containerized ordnance into palletized ordnance is significant when looking at the best performing scenarios in the experiments. Lastly, the analysis clearly showed that improving the system performance is not dependent on the distance of ordnance storage facilities from the wharf, but rather on the volumetric capability of the system.

KEYWORDS: Arena, Design of Experiments, DOE, Logistics, Naval Supply, Ordnance, Simulation

DEVELOPING AND ASSESSING THE PEACE SUPPORT OPERATIONS MODEL

Thomas W. Lucas, Associate Professor
Susan M. Sanchez, Professor
Department of Operations Research
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To explore the Peace Support Operations Model (PSOM) to better understand data requirements, model behavior, and how best to use it to provide insights into irregular warfare (IW).

SUMMARY: The need for tools to address the IW environment is a pressing requirement. One emerging modeling platform that has been identified as an exciting candidate is the Peace Support Operations Model (PSOM), developed by the U.K.’s Defense Technology and Systems Laboratory. As with many models, there are a large number of highly uncertain inputs. This research focused on getting PSOM into an environment that enables us to efficiently experiment with it. This includes the functionality for running PSOM via a command line and on a computing cluster. These capabilities were implemented and tested. Tools for assembling the information from the numerous output files into a form more manageable for analysis were implemented and demonstrated.

PUBLICATION:


PRESENTATION:

KEYWORDS: Design of Experiment, DOE, Peace Support Operations, PSO, Simulation

AN EVALUATION OF MARINE CORPS TOTAL LIFE CYCLE MANAGEMENT
Thomas W. Lucas, Associate Professor
Susan M. Sanchez, Professor
Department of Operations Research
Sponsor: United States Marine Corps Installation and Logistics

OBJECTIVE: To use advanced design of experiments (DOE) and simulation to improve the Marines’ ability for total life cycle management (TLCM).

SUMMARY: Life cycle management (LCM) is defined as a decision-making process that takes into consideration the benefits, costs, and risks associated with each action over the full life cycle of a system. Effective LCM requires good forecasting to help determine future requirements for design and development, acquisition, in-service support and sustainment, modernization, and final disposal of a fleet of systems. It is in forecasting that simulation tools play a key role in LCM by helping program managers gain insights into their supported systems. The Total Life Cycle Management Assessment Tool (TLCM-AT) is a probabilistic modeling and simulation analysis tool developed to support and improve the U.S. Marine Corps’ LCM. This powerful tool is capable of performing “what-if” scenario analysis to compare the merits of multiple courses-of-action or policies. Unfortunately, such analytical results are predicated on a set of conditions developed in the model that have little chance of occurring in real life. This research combined the capabilities of TLCM-AT with the benefits of a sophisticated DOE to enable in-depth sensitivity analysis of alternatives. This new capability was demonstrated in an exemplar analysis of a scenario deploying LAV-25 vehicles to a tropical region, with three courses of action. The research provided a description of the analysis available by TLCM-AT as a stand-alone tool and concluded with how DOE expands insights gained.

PUBLICATION:

THESES DIRECTED:


KEYWORDS: Design of Experiments, DOE, Life Cycle Management, LCM, Simulation
OBJECTIVE: Using simulation, assess how best to use new systems, such as the Ground-Based Operational Surveillance System (G-BOSS), in the counter-improvised, explosive device (IED) fight.

SUMMARY: The majority of casualties in the ongoing conflicts in Iraq and Afghanistan are due to IEDs. To counter this threat, the Marine Corps directed that a persistent surveillance capability be identified and fielded as soon as possible. As a result, the development and fielding of the Ground-Based Operational Surveillance System (G-BOSS) occurred rapidly. G-BOSS consists of a tower, multiple cameras, and a combat operations center (COC). Today, scores of these systems are in use. However, minimal guidance has been provided to operators on effective techniques, tactics, and procedures (TTPs). Furthermore, the benefits of adding additional sensors to G-BOSS and networking multiple systems are not clear. This research investigated these issues through the use of an agent-based simulation. Specifically, thousands of computational experiments (utilizing a state-of-the-art experimental design) were run on a scenario based on concurrent, live, developmental tests conducted at Twenty-Nine Palms by the Marine Corps Operational Test and Evaluation Activity. The experiments assessed the ability of the system to correctly classify threats (e.g., snipers, IED emplacement, and mortar teams, as well as neutrals and friendly forces) over a variety of enemy actions, G-BOSS configurations, and tactical choices. The results indicated that the most critical factor in determining the level of situational awareness provided by G-BOSS is, by far, placement of the towers. Moreover, little benefit was seen in coordinating the towers and COCs unless motion detection radars were used. With use of the motion detection radar, the synchronization of multiple systems dramatically enhanced the overall performance of G-BOSS.

PRESENTATION:


THESIS DIRECTED:


KEYWORDS: Design of Experiment, DOE, Improvised Explosive Device, IED, Ground-Based Operational Surveillance Sensor, G-BOSS, Simulation
preparation, field data collection, data analysis, and reporting of field testing of soldier technologies at Fort Dix, New Jersey.

PRESENTATION:


KEYWORDS: Future Warrior Technology Integration, Soldier Support Systems, Soldier Performance, Soldier Medical Monitoring, Conformal Battery

HUMAN PERFORMANCE ONBOARD A HIGH-SPEED CATAMARAN

Michael E. McCauley, Research Professor
Department of Operations Research
Sponsor: Naval Surface Warfare Center-Panama City

OBJECTIVE: To evaluate the effects of ship motion on human performance during transit of the high-speed catamaran FSF-1 Sea Fighter from Florida, through the Panama Canal, to the Pacific Northwest.

SUMMARY: This was one evaluation in a continuing series to determine human performance characteristics as affected by high-speed vessel motion. In cooperation with the sponsor’s research office, ship-motion data were recorded full-time, and periodic measures-of-performance in perceptual-motor and manual-dexterity tasks were collected. In addition, wrist activity monitors were used to evaluate sleep duration and quality and as a new approach to an objective measure of Sopite Syndrome, a subset of motion sickness. This line of research will continue in CY2009 with tests of the littoral combat ship (LCS) and the LCS Anti-Submarine Warfare Mission Module.

KEYWORDS: Sopite Syndrome, High Speed Vessel, Crew Performance, Non-Linear Regression Model, Habitability

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS

Nita Lewis Miller, Associate Professor
Department of Operations Research
Sponsor: United States Special Operations Command

OBJECTIVE: To provide an objective way to assess the benefit of new technology to the warfighter.

SUMMARY: The experiment was designed to test the value of additional technology by using the AWARE tool. Valid and objective assessments of new systems depend on a variety of factors. These include the selection and training of the personnel who are testing the new technology, the test scenarios that are used, and the ability to evaluate how the technology is employed. These issues, while challenging to accomplish, are vital in order to have unbiased testing and evaluation of new technology. Field data was collected at the TNT exercises at Camp Roberts using the AWARE tool, which allowed quantitative estimates of situation awareness of operators in the field.

KEYWORDS: UAVs, Unmanned Systems, Operator Workload, Human Performance
HUMAN-SYSTEMS-INTEGRATION TRADESPACE TOOL DEVELOPMENT
Nita Lewis Miller, Associate Professor
Department of Operations Research
Sponsor: United States Air Force Human Performance Wing

OBJECTIVE: To provide a decision support tool for program managers to assess the tradeoffs among his domains and standard system acquisition metrics of cost schedule, risk, and performance.

SUMMARY: Quantitative measures for human systems integration (HSI) are limited to a few instances of design and alternatives for architecting systems. Without substantive, quantifiable measures that are both reproducible and scalable, the integration of humans into a complex decision environment can be both inefficient and ineffective. Specifically, the application of best-practice systems engineering fails to account for inadequacies in both design and architecture. The scope of this work is to determine the measures and metrics of HSI designs and then to incorporate those factors into alternative architectures through a deterministic set of value constructs. The outcome of this effort will be a definitive set of measures-of-performance and measures-of-effectiveness from which to determine the degree of appropriateness in which a design and architecture satisfies a set of requirements. Using contributions from fields such as value systems engineering, the goal of the project is to accurately represent an understanding of design and architecture within the practices and structures of HSI requirements. The project is on-going.

KEYWORDS: Value-Based Engineering, Tradespace, Tradeoff Analysis

A LONGITUDINAL STUDY OF CADET SLEEP PATTERNS
Nita Lewis Miller, Associate Professor
Lawrence G. Shattuck, Senior Lecturer
Department of Operations Research
Sponsor: PEO Soldier (United States Army)

OBJECTIVE: To continue the study of U.S. Military Academy (USMA) cadet sleep patterns; examine the effects of sleep deprivation on performance; apply what is learned at the USMA to help predict soldier performance on the battlefield; and develop an easy-to-use tool so that commanders can assess the “fightability” of their unit.

SUMMARY: The research team continued the longitudinal study of the West Point Class of 2007. Activities completed included: completion of sleep data analysis, additional analysis of napping behavior, development of recommendations to improve performance at the USMA, administered surveys to officers returning from Iraq to determine sleep hygiene issues associated with sustained combat operations, and continued to work on a method that could be used by leaders to assess and predict performance based on sleep hygiene.

KEYWORDS: Sleep, Sleep Hygiene, Fatigue, Sleep Deprivation

THE OPERATIONAL CONSEQUENCES OF HUMAN FATIGUE ON PERFORMANCE AND MANNING STRATEGIES IN MILITARY ENVIRONMENTS
Nita Lewis Miller, Associate Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To provide an objective way to assess the benefit of new technology to the warfighter. This research proposed to examine the operational consequences of human fatigue on performance in military environments. The project will assess how fatigue impacts performance in the U.S. military and will look at what fatigue countermeasures are currently being used. It will propose and test strategies to mitigate the risks posed by under-manning and the reduced/restricted sleep regimens imposed by the
military on its individual service members. Furthermore, the proposed work will result in a published guide for fatigue management for commanders to use in operational environments. The project is ongoing.

**KEYWORDS:** UAVs, Operator Workload, Fatigue, Human Performance

**NAVAL POSTGRADUATE SCHOOL COST ANALYSIS SUPPORT FOR THE COST ANALYSIS IMPROVEMENT GROUP**

*Gregory K. Mislick, Senior Lecturer*

*Department of Operations Research*

*Sponsor: Office of the Secretary of Defense, Cost Analysis Improvement Group*

**OBJECTIVE:** To support activities related to the investigator’s role as Chair of Cost Analysis during CY2008. The Office of the Secretary of Defense (OSD), Cost Analysis Improvement Group (CAIG) at the Pentagon is tasked to provide independent cost estimates on all major defense acquisition programs.

**SUMMARY:** OSD, CAIG requested that the principal investigator (PI) secure a Naval Postgraduate School (NPS) student (or two) to conduct thesis research on costing topics of interest to both the Department of Defense (DoD) and OSD, CAIG. This research is in support of DoD weapon systems acquisitions. This year, operations research student LT E. Zephyr Rienteau, USN, worked on an OSD, CAIG topic entitled “A Comparative Analysis of Podded versus Mechanically Driven Propulsion Systems.” The results support that the U.S. Navy should integrate electrically driven, podded propulsors on future auxiliary ship design based on the impact of design, construction, and operation costs. LT Rienteau is scheduled to graduate in March 2009.

The proposal paid for all travel and expenses incurred by the thesis student during his thesis tour to OSD, CAIG in November 2008. It also allowed the PI to travel to the annual DoD Cost Analysis Symposium held in Williamsburg, Virginia, each February. This symposium brought together a large number of cost estimators from the DoD, industry, and academia. The four-day symposium connected cost estimators and analysts in a highly informative fashion with the goals of increasing the accuracy of weapon acquisition cost estimates and understanding how to deal with the risks that are inherent in large, state-of-the-art, weapon-systems purchases. It also offered a useful selection of educational and training opportunities on best practices and the state-of-the-art in cost estimating. Information gained during this symposium was then added to the course material for the OA4702 Cost Estimation class, keeping it continually relevant and current.

**KEYWORDS:** Podded Propulsion, Mechanically Driven Propulsion, Naval Auxiliary, Comparative Analysis, Net Present Value, Learning Curve

**IMPROVING AND INCORPORATING COST ESTIMATING AND ANALYSIS INTO ADVANCED CONCEPT TECHNOLOGY DEMONSTRATIONS**

*Daniel A. Nussbaum, Visiting Professor*

*Department of Operations Research*

*Sponsor: Office of the Under Secretary of Defense for Advanced Systems and Concepts*

**OBJECTIVE:** To develop business case analyses (BCA) for specific Advanced Concept Technical Demonstrations/Joint Concept Technical Demonstrations.

**SUMMARY:** This project developed a methodology to provide senior Deputy Under Secretary of Defense for Advanced Systems and Concepts (DUSD (AS&C)) decision-makers with improved, consistent, credible, and reliable cost estimates to evaluate the Advanced Concept Technical Demonstration/Joint Concept Technical Demonstration (ACTD/JCTD) Program. It included an enhanced understanding of the unique characteristics of the ACTD/JCTD Program and provided business case analyses for several candidate ACTD/JCTD projects. The study provided a series of rigorous analyses of the costs and benefits associated with the projects and thereby provided an analytic underpinning to the funding decisions for
initialization or continuation of candidate projects. Additionally, the work supported transition planning with the joint staff.

PRESENTATIONS:


Nussbaum, D., “Presentation to NATO School Faculty,” NATO School, Oberammergau, Germany, 2 December 2008.


THESES DIRECTED:


KEYWORDS: Cost Estimating, Business Case Analysis, Advanced Concept Technical Demonstration, ACTD, Joint Concept Technical Demonstration, JCTD
A PRELIMINARY ASSESSMENT OF U.S. ARMY WATER AND PETROLEUM DISTRIBUTION
Daniel A. Nussbaum, Visiting Professor
Department of Operations Research
Sponsor: Advanced Concepts and Technologies International (CRADA)

OBJECTIVE: To assess alternative means of distributing petroleum, water, and other strategic energy resources, including alternative fuels.

SUMMARY: This joint research effort for the Department of Defense (DoD) aimed at analyzing the impact of alternative energy on water and petroleum distribution for U.S. Army facilities and installations. In collaboration with Advanced Concepts and Technologies International (ACTI), the Naval Postgraduate School (NPS) evaluated global and regional environmental factors to determine the need for and design of a DoD Alternative Energy Center. This included two short-term studies that investigated the following: 1) a systems engineering approach and modeling and simulation development of an energy infrastructure for U.S. Army facilities and installations; and 2) identification of the high-priority water and alternative-energy development options for the DoD, analysis of the environmental factors that affect those options, and assessment of the potential impacts of those factors on the supply of and demand for these options.

TECHNICAL REPORTS:

KEYWORDS: Water Distribution, Petroleum Distribution, Department of Defense, DoD, U.S. Army, Modeling and Simulation, M&S

PROVIDING ANALYTICAL SUPPORT TO THE U.S. AIR FORCE QUADRENNIAL DEFENSE REVIEW
Daniel A. Nussbaum, Visiting Professor
Department of Operations Research
Sponsor: United States Air Force Quadrennial Defense Review

OBJECTIVE: To examine potential U.S. Air Force research objectives in support of the Quadrennial Defense Review (QDR).

SUMMARY: Several research projects were identified and refined in collaboration with the U.S. Air Force QDR Office. The objective was to establish partnership opportunities between the Naval Postgraduate School (NPS) and the Air Force Institute of Technology (AFIT) in support of AF QDR Office research. The following projects have been established and are in progress:

• “Impacts of Global Climate Change on U.S. Air Force,” Professor Tom Murphree, Department of Meteorology, NPS
• “Low Earth Orbit (LEO) Satellite Vulnerabilities,” Professor Ramesh Kolar, Department of Mechanical and Astronautical Engineering, NPS
• “Requirements and Capabilities for the Treatment of Climate Change,” Professor Peter Chu, Department of Oceanography, NPS
• “Development of ‘Bent’ Functions for Use in Encrypting and Decrypting Plaintext Messages,” Professor Jon T. Butler, Department of Electrical and Computer Engineering and Professor Pantelimon Stanica, Department of Applied Mathematics, NPS
PRESENTATION:


TECHNICAL REPORTS:


KEYWORDS: United States Air Force, USAF, Quadrennial Defense Review, QDR, Air Force Institute of Technology, AFIT, Collaborative Research

A VALUE-BASED OPTIMIZATION APPROACH FOR PROGRAMMING THE ARMY’S TOTAL OBLIGATION AUTHORITY

Daniel A. Nussbaum, Visiting Professor
Department of Operations Research
Sponsor: United States Army Training and Doctrine Analysis Center–Monterey

OBJECTIVE: To examine potential retention incentives, both monetary and non-monetary, for first-term enlisted soldiers and officers in the United States Army Reserve.

SUMMARY: The analysis identified and examined potential retention incentives, both monetary and non-monetary, for first-term enlisted soldiers and officers in the United States Army Reserve. The examination systematically determined the most demanded, clearly defined, and Army Reserve-specific incentives that plausibly improve retention. It identified and described the resulting list, along with appropriate limitations and assumptions. Additionally, it developed methodologies for estimating the costs of these incentives and produced cost estimates for each of the incentives based on available data. It also described follow-on analysis to construct an incentive portfolio that could be used to better allocate programming dollars over a six-year program objective memorandum (POM) horizon.

The study relied on data from two concurrent studies performed by the Training and Doctrine Command Analysis Center at Fort Lee (TRAC-LEE), as well as data from the Defense Manpower Data Center. The data elements from the TRAC-LEE studies included over 20,000 surveys, 200 interviews, and information on how educational assistance impacts the Army Reserve’s end-strength.

THESIS DIRECTED:


KEYWORDS: United States Army Reserve, USAR, Retention, Incentives, Cost Estimation
OBJECTIVE: To invigorate and conduct research and analysis to develop Naval doctrine, tactics, techniques, procedures, and maritime and joint operational concepts.

SUMMARY: The Chair of Warfare Innovation is tasked by Memorandum of Agreement between the Naval Postgraduate School and the Navy Warfare Development Command (NWDC) to act as an initial point of liaison for NWDC to coordinate collaborative research efforts across a wide span of research opportunities. To this end, the Chair of Warfare Innovation administers funding for faculty and student research in accordance with established NPS research guidelines. This may include, but will not be limited to, faculty labor, staff labor, travel, equipment, supplies, and contracts and services.

TECHNICAL REPORTS:

Tactical Memorandum (SECRET), Project 08-01.

THESIS DIRECTED:


KEYWORDS: LCS, HARPY, Optimization, Force Structure, ASROC, Sonar, Anti-Satellite

OBJECTIVE: To develop algorithms for solving difficult optimization problems where the objective and/or constraint functions cannot be computed exactly, but must be approximated. Particular focus is on the construction of efficient precision-adjustment schemes for controlling the approximations within algorithms.

SUMMARY: This research is directed towards three classes of optimization problems: 1) stochastic programs, where functions are defined in terms of expectations, 2) semi-infinite programs, where functions are non-smooth max-functions, and 3) optimal control problems, where functions are given by the solution of ordinary and partial differential equations. In 2008, research was initiated on class 1), i.e., stochastic programs, and results were obtained that showed the potential for significant computational savings when the precision of approximations was controlled by a discrete-time optimal-control problem. Moreover, advances were made towards characterizing the asymptotic probability distribution of various estimators related to stochastic programs. This enabled a better understanding of the trade-offs between estimation
errors due to sampling and incomplete optimization of sample average approximations. Research on classes (2) and (3) was initiated in fall 2008.

PRESENTATIONS:


KEYWORDS: Nonlinear Optimization, Stochastic Programming, Semi-Infinite Optimization, Optimal Control

OPTIMIZATION MODELS AND ALGORITHMS FOR PATHFINDING PROBLEMS

Johannes O. Royset, Assistant Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To develop algorithms for solving optimal routing problems when one or more searchers look for a non-evading target.

SUMMARY: The principal investigators (PI) formulated and solved a discrete-time path-optimization problem where single or multiple searchers operating in a discretized, three-dimensional airspace look for a moving target in a finite set of cells. The searcher was constrained by maximum limits on search time, and possibly fuel consumption and risk exposure along any path. The PIs developed a specialized branch-and-bound algorithm for this problem that utilized several network reduction procedures and a new bounding technique based on Lagrangian relaxation and network expansion. The resulting algorithm outperformed a state-of-the-art algorithm for solving time-constrained problems and was the first algorithm to solve multi-constrained problems. The PIs developed a cutting plane algorithm for solving problems with multiple searchers. This research resulted in a paper submitted for publication in 2008 and a Ph.D. dissertation.

PUBLICATION:


DISSERTATION DIRECTED:


KEYWORDS: Nonlinear Integer Programming, Stochastic Optimization, Search Theory
EXTENSIONS OF NETWORK INTERDICTION AND DEFENSE
Javier Salmeron, Associate Professor
Department of Operations Research
Sponsor: Naval Postgraduate School, Research Initiation Program

OBJECTIVE: To develop and test models for optimal interdiction and defense.

SUMMARY: This research helped develop and test mathematical models and algorithms for optimal network interdiction (disruption) and defense. Specifically, the study focused on two areas: a) “tri-level” models, which arise when planning the defense of a network “threatened” by a standard, bilevel interdiction model; and b) generalization of the paradigm of transparent (perfect) information, by allowing misperception on either side. This case modeled attackers who did not have a complete representation of the system to be interdicted, e.g., when some information has intentionally been hidden by the system defender in order to deceive potential aggressors.

PUBLICATION:

PRESENTATION:

THESES DIRECTED:


KEYWORDS: Network Interdiction

JOINT MISSION EFFECTIVENESS SUPPORT USING DATA FARMING
Susan M. Sanchez, Professor
Gary E. Horne, Research Assistant Professor
Department of Operations Research
Sponsor: Netcentric Systems Test Program

OBJECTIVE: To develop models and data farming techniques to support the testing of mission effectiveness in a variety of joint system-of-system environments and scenarios.

SUMMARY: The Naval Postgraduate School (NPS) SEED Center for Data Farming Team is supporting the overall NST need to conduct testing in a complex, joint-mission environment across the acquisition lifecycle to improve a program manager’s ability to deliver joint capabilities to warfighters. For a joint mission environment with many interdependent systems, assessing individual system and system-of-systems (SoS) contributions to joint mission effectiveness becomes extremely challenging. This complex, adaptive, SoS environment makes it nearly impossible to plan efficient tests using current test methods and capabilities. Cogent planning for the tests of these complex, adaptive systems involves a very tedious, almost impossible, test-planning process for determining what and how exactly to test.

In this project, progress was made in the two areas of understanding the vast possibility spaces in joint mission environments and representing the cognitive command-and-control capabilities inherent in joint
activity. This past year, the research team demonstrated the usability of the model in conjunction with data farming; based on these results, the project will further develop the technology to support the discovery of battlespace interoperability opportunities and challenges in the testing of systems and networks of systems. This effort leveraged the strengths of the data farming and design-of-experiments work within the department.

PUBLICATIONS:


CONFERENCE PUBLICATION:


**COMBAT SERVICE SUPPORT (CSS) SOLDIER NETWORK-ENABLED OPERATIONS CAPABILITIES-BASED ASSESSMENT**  
Lawrence G. Shattuck, Senior Lecturer  
Nita Lewis Miller, Associate Professor  
Department of Operations Research  
Sponsor: TRADOC Analysis Center-Monterey

**OBJECTIVE:** To assist TRAC–Monterey in conducting a capabilities-based assessment (CBA) to investigate the extent to which U.S. Army Combat Service Support (CSS) soldier performance will be enhanced by network-enabled technologies.

**SUMMARY:** Dr. Shattuck and Dr. Miller consulted on all stages of a capabilities-based assessment for Combat Service Support soldiers (specifically, MOS 88H, 88M, and 88N) in forward operating bases. In particular, they were involved with survey construction and analysis and focus group interviews. These activities supported the functional area analysis and included assessing the appropriateness of the current list of tasks, conditions, and standards. They also assisted with efforts related to the functional needs analysis (FNA), capability gap analysis, and functional solutions analysis. Other activities included: task mapping (UJTL/AUTL…Individual Soldier) (FAA); assisting in the development of conditions and standards for identified tasks (FAA); questionnaire development and execution (FAA/FNA/FSA); risk assessment (FNA/FSA); application of multi-attribute decision-support tools to the DOTMLPF domain (FSA); synthesis of results (FAA/FNA/FSA); and assisting in preparation of results for all reports.

**KEYWORDS:** Capabilities Based Assessment, Capability Gaps, Functional Area Analysis

**FUTURE WARFIGHTER TECHNOLOGY INTEGRATION**  
Lawrence G. Shattuck, Senior Lecturer  
Nita Lewis Miller, Associate Professor  
Department of Operations Research  
Sponsor: TRADOC Analysis Center-Monterey

**OBJECTIVE:** To provide support to the Future Warrior Technology Integration Project under the direction of TRAC-Monterey. Support spanned the entire project timeline, including experimental design, experimentation and data collection, and post-experiment analysis.
SUMMARY: Aided in the development of problem definition, including issues for analysis and essential elements of analysis; contributed to the development of the experimental design in support of human-system-integration issues and human-factors-related issues; developed appropriate measurement instruments to address identified issues for analysis in support of a live experimentation event; contributed to the development and execution of a data-collection plan in support of the live experiment; conducted additional further analysis on operator workload issues; and documented results in briefings and technical reports.

KEYWORDS: Raven UAV, Operator Workload, Human Performance

AN INVESTIGATION OF AMBIGUITY AND ITS IMPACT ON MILITARY DECISION-MAKERS
Lawrence G. Shattuck, Senior Lecturer
Nita Lewis Miller, Associate Professor
Department of Operations Research
Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To investigate the impact of ambiguity on decision-making in the U.S. Army. The knowledge gained from this effort was used to develop software agents that function similar to human agents who are faced with uncertain, ambiguous, complex, conflicting, or missing data.

SUMMARY: Dr. Miller and Dr. Shattuck assisted TRAC with an initial literature review. Based on the results of the literature review, a determination was made to collect data through interviews and laboratory experimentation. Dr. Miller and Dr. Shattuck analyzed the data and made recommendations to TRAC on the most appropriate ways to construct software agents that reason about uncertainty in a manner similar to human decision-makers. Specific tasks accomplished included: assisted TRAC in conducting a review of the scientific literature on the manner in which humans reason about uncertainty and related constructs, including ambiguity, trust, and confidence; designed a data collection event at both the Naval Postgraduate School (NPS) and at the Command and General Staff College, Ft. Leavenworth, Kansas; collected data using Army officers at both NPS and Ft. Leavenworth, Kansas; analyzed data and reported results; and made recommendations on the attributes that should be built into software agents.

THESIS DIRECTED:

KEYWORDS: Uncertainty, Ambiguity, Decision Making

SENSOR TO COMMANDER METRICS
Lawrence G. Shattuck, Senior Lecturer
Nita Lewis Miller, Associate Professor
Department of Operations Research
Sponsor: Army Research Office

OBJECTIVE: To continue refinement of the Dynamic Model of Situated Cognition, to provide consultation to graduate students who are working in this field of research, and to continue development of the AWARE tool.

SUMMARY: The Dynamic Model of Situated Cognition (DMSC) has successfully integrated technological and human elements into a single, conceptual framework (Miller and Shattuck, 2004a; 2006). This model describes the interaction between technological and human agents in complex systems. It has been used retrospectively to explain how activities can go awry in complex systems (Shattuck and Miller, 2006; Miller, Shobe, and Shattuck, 2005). Tracing the flow of events through the model often reveals that
whereas the initial finding may be “human error,” the actual cause may be rooted in the technology. The model also has been used as an analytical framework for military command and control simulation experiments (Miller and Shattuck, 2004b) and for illustrating the role of Red-force interaction in force-on-force war games (Miller, Miller, and Shattuck, 2007). This research further developed the DMSC model and continued efforts to transition it to a computational model. A software tool that allows more effective collection of field data and provides feedback in a timely manner was developed. The AWARE tool was successfully demonstrated at multiple Tactical Network Topology exercises.

**KEYWORDS:** Situated Cognition, Situation Awareness, Human Performance

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**U.S. MARINE CORPS TACTICAL COMMAND AND CONTROL**

Lawrence G. Shattuck, Senior Lecturer  
Nita Lewis Miller, Associate Professor  
Department of Operations Research  
Sponsor: Office of Naval Research

**OBJECTIVE:** To provide technical research and serve as subject matter experts (SME) for the DOTC2 project, focusing efforts on human factors, human systems integration, team performance, human performance, and information processing.

**SUMMARY:** Conducted a detailed task analysis of Marine Corps warfighting doctrine at the team, squad, platoon, and company level. The method followed for this project was a three-pronged approach that corresponded closely to the JCIDS requirements of functional area analysis, functional needs analysis, and functional solutions analysis (FAA, FNA, and FSA). The analysis was used to determine the impact of the U.S. Marine Corps’ distributed operations (DO) doctrine on mission accomplishment. The doctrine suggests that the activities of a platoon under the current doctrine should be performed by a squad under the DO doctrine. The analysis revealed that while some missions could still be accomplished, others would be severely impacted due to lack of firepower and other resources, insufficient personnel, or an inability to cover enough terrain.

**REPORT:**


**KEYWORDS:** Distributed Operations, Task Analysis, Functional Decomposition

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**HUMAN FACTORS EVALUATION OF A FUTURE COMBAT SYSTEM COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS, INTELLIGENCE, SURVEILLANCE, RECONNAISSANCE (C4ISR) SENSOR SUITE IN ISR MISSIONS**

Jeffrey Alexander Thomas, Research Associate  
Department of Operations Research  
Sponsor: Army Research Laboratory - Survivability Lethality and Analysis Directorate

**OBJECTIVE:** To provide experimental design, data collection, and analysis support for the Cognitive Impacts Study led by the Army Research Laboratory–Survivability Lethality and Analysis Directorate (ARL-SLAD), in support of the Product Manager Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance (C4ISR) On-the-Move (PM C4ISR OTM) Experiment/Exercise 2008 (E08). This effort is focused on assessing the human systems integration of a fully instrumented Future Systems Combat Soldier Platoon.

**SUMMARY:** The principal investigator worked with an interdisciplinary research team to design and execute a field study to assess the cognitive impacts of the employment of integrated C4ISR systems. To
conduct this study, a company-sized element from the 1/29th Infantry Regiment, Fort Benning, Georgia, was organized into two reconnaissance platoons and a company headquarters element. Each platoon was equipped with mounted and dismounted communications and battle command devices. Additionally, each platoon used unmanned ground sensors; small, unmanned ground vehicles; and several unmanned and manned aerial-sensor platforms.

This study captured observational, subjective, and objective data to assess soldiers’ use of technologies to obtain, share, and make sense of information about an adaptive enemy force. Measures of cognitive performance included workload, situational awareness (SA), and trust in the network. The results indicated that the ability of soldiers to use technology to develop their SA picture and to communicate within and between units is a function of the ability of the robotics non-commissioned officer (Robo NCO) in both platoons to fuse/integrate information from multiple ISR sensors. Soldiers repeatedly lost SA and compromised their personal security when the technology/network failed. As a primary goal of PM C4ISR OTM E08, the Cognitive Impact Study represented the first major field investigation of this problem at the tactical level.

TECHNICAL REPORTS:


KEYWORDS: Cognitive Performance, Situational Awareness, Workload, Unmanned Aerial Vehicle

INTERDICTING THE IMPROVISED EXPLOSIVE DEVICES (IED) SUPPLY CHAIN

R. Kevin Wood, Professor
Javier Salmeron, Associate Professor
Department of Operations Research
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To develop and implement a model for optimal interdiction of smuggled improvised explosive devices (IEDs) and IED components.

SUMMARY: A game-theoretic model was applied to the interdiction of IEDs and/or IED components. The model identified an optimal, randomized strategy for allocating limited search teams along road segments. The model was also implemented using the VBA programming language (Visual Basic for Applications), and was embedded within an Excel-based graphical-user interface. The implementation handled networks with 10,000-100,000 road segments and any number of homogeneous search teams.

KEYWORDS: Network Interdiction, Improvised Explosive Devices

LARGE-SCALE NETWORK ALGORITHMS

R. Kevin Wood, Professor
W. Matthew Carlyle, Associate Professor
Department of Operations Research
Sponsor: National Security Agency

OBJECTIVE: To provide support for continuing research on network-interdiction and other types of attacker-defender problems.

SUMMARY: The research team has successfully implemented models and solution algorithms for interdicting a nuclear weapons project and interdicting an electric power grid. The algorithm for solving
the first model used a novel decomposition scheme with nominally non-convergent bounds: solution-elimination constraints yielded a convergent algorithm.

PUBLICATIONS:


PRESENTATIONS:


KEYWORDS: Network Interdiction, Attacker-Defender Models, Bilevel Optimization

A NEW PERSPECTIVE ON FEASIBILITY DETERMINATION
Enver Yucesan, INSEAD
Roberto Szcchtman, Assistant Professor
Department of Operations Research
Sponsor: GEE Funds

OBJECTIVE: To develop algorithms that can efficiently determine the feasibility or infeasibility of a large number of stochastic systems.

SUMMARY: The problem of feasibility determination in a stochastic setting was considered. The goal was to determine whether a system belongs to a given set based on a performance measure estimated through Monte Carlo simulation. The contribution of the principal investigators (PIs) was twofold: 1) the PIs characterized fractional allocations that are asymptotically optimal; and 2) the PIs provided an easily implementable algorithm, rooted in Stochastic Approximation Theory, that results in sampling allocations that provably achieve in the limit the same performance as the optimal allocations. The finite-time behavior of the algorithm was illustrated on two small examples.

CONFERENCE PUBLICATION:


PRESENTATION:

KEYWORDS: Monte Carlo Simulation, Feasibility Determination, Stochastic Approximation, Large Deviations
DEPARTMENT OF OPERATIONS RESEARCH

2008
Faculty Publications and Presentations


**CONFERENCE PUBLICATIONS**


**PRESENTATIONS**


Miller, N.L. and Shattuck, L.G., “The Human Systems Integration Laboratory: Facilities, Capabilities, and Recent Activities,” Presented to Mr. Michael Bauman, SES, Director, TRADOC Analysis Center, Naval Postgraduate School, 1 April 2008.


Nussbaum, D., “Presentation to NATO School Faculty,” NATO School, Oberammergau, Germany, 2 December 2008.


**BOOK**


**CONTRIBUTIONS TO BOOKS**


**TECHNICAL REPORTS**


**SOFTWARE**

Bradley, G., Naval Postgraduate School SIGACTS Viewer.
GRADUATE SCHOOL OF ENGINEERING AND APPLIED SCIENCES

JAMES KAYS
DEAN
DEPARTMENT OF APPLIED MATHEMATICS

CLYDE SCANDRETT
CHAIR
OVERVIEW:
The Naval Postgraduate School (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 SERVED:
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
- Discrete Mathematics
- Numerical Modeling

RESEARCH PROGRAM (Research and Academic)-FY2008:
The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. 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: $320K
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A REQUIREMENTS SEARCH ENGINE
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Ralucca Gera, Assistant Professor
Department of Applied Mathematics
Craig Martell, Associate Professor
Kevin Squire, Assistant Professor
Department of Computer Science
Sponsor: PEO IWS 7.0

OBJECTIVE: This research addresses three closely related problems. One, most current search technology is based on a popularity metric (e.g., PageRank or ExertRank), but not on the semantic content of the document. Two, when building components in a service-oriented architecture (SOA), it is often necessary to check if components that meet certain requirements already exist. Three, there is no easy way for writers of requirements documents to formally specify the meaning and domain of their requirements. This proposed project will produce a prototype search-engine designed to search over the “meaning” of requirements documents, provide a road-map for future work to build a robust requirements-document search engine, and provide prototype tools to the requirements-document author that limit ambiguity and specify the requirements in a semi-formal, searchable representation.

KEYWORDS: Semantic Search, Requirements, Open Architecture

A FULL-NEWTON ALGORITHM FOR DISCRETE, RATIONAL, LEAST-SQUARES PROBLEMS
Carlos F. Borges, Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: To develop a full-Newton algorithm for discrete, rational, least-squares problems.

SUMMARY: This unfunded effort is part of a continuing research project. The general idea is to fit parametric polynomial spline curves to ordered data to get the best possible fit. Unlike traditional least-squares methods, it is assumed that errors may occur in both the x and y directions. Moreover, the data is allowed 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. Last year, the author completed the derivation of a full-Newton algorithm for general, separable, nonlinear, least-squares problems. This year, the author has implemented and tested the general algorithm and developed and implemented an important special case – the solution of discrete, rational, least-squares approximation problems. The author completed a paper covering these algorithms and it is scheduled to appear in ETNA.

KEYWORDS: Curve Fitting, Rational Approximation, Approximation Theory

ALGEBRAIC ATTACKS ON THE ADVANCED ENCRYPTION STANDARD
David Canright, Associate Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: To examine cryptographic attacks on the Advanced Encryption Standard algorithm, based on solving algebraic equations that describe the algorithm. Of particular interest is a new approach called Multiple Right-Hand Side (MRHS) equations. This work is ongoing.
SUMMARY: Algebraic attacks on cryptographic algorithms have previously been explored, so far without any resulting attack being more efficient than brute-force key search. Much of this work involves multivariable polynomial equations over the binary Galois Field, GF(2), for the individual bits in intermediate results of encryption rounds. (Over a finite field, any non-linear function can be expressed as a polynomial function.) Methods employed for solving these equations include Extended Linearization (XL) and Extended Sparse Linearization (XSL). Another recent approach explores attacking AES using equations over the larger field GF(256), in which most of the operations of AES are defined. Typical methods involve Gröbner basis methods.

Late in 2007, the principal investigator (PI) came across new work by a team in Bergen, Norway. They had developed a novel approach, which they called Multiple Right-Hand Side equations. This is not the same as a linear system with multiple right-hand sides representing different data vectors for which the system should be solved. Rather, here the multiple right-hand sides represent the set of all valid outputs of the system. Any nonlinear equation over a finite field can be expressed in this way by simply listing the possible outputs. They described methods for solving systems of such MRHS equations, and, for a “toy” version of AES, were able to break the key, as had been done by others using Gröbner basis tools; but the MRHS approach was roughly six orders of magnitude faster.

In 2008, the PI had a Master’s student in the Electrical and Computer Engineering Department, Panteleimon Mantzouris. The Norwegian team was kind enough to provide some of their code (though, curiously, could not provide a complete working version); the code was used to develop an interactive implementation of MRHS. The PI also wrote software to generate the MRHS equation systems for small variants of AES. This allowed the student to explore the different techniques (agreeing, gluing, linear extraction, guessing) used for MRHS systems. One surprise he discovered is that for some small AES variants, a given plaintext/ciphertext pair may have more than one valid key.

In fall 2008, Pantelimon Stănică and the PI submitted a research proposal to AFOSR, seeking support to work on MRHS equations. A decision has not yet been made.

In 2008, a Ph.D. student, CPT Natalie Vanatta, agreed to work with the PI on the MRHS topic. She began work in January 2009. One particularly promising topic is extending the “agreeing” technique, where pairs of MRHS equations are compared to eliminate inconsistent right-hand sides, to agreeing n-tuples of equations, using graph theory.

THESIS DIRECTED:


KEYWORDS: Cryptography, AES, Algebraic Attacks, Galois Fields, MRHS
operation, which had been realized in Verilog (a hardware description language) and tested on an FPGA. A 2007 technical report includes the Verilog code. The PI optimized the circuit at several levels for minimal size, as was done for the unmasked S-box in previous work.

A paper was presented at the 6th International Conference on Applied Cryptography and Network Security (ACNS), June 3-6, at Columbia University in New York. While reviewing related work in preparing for the talk, the PI discovered a technical problem in the result, which had resulted from misinterpreting a certain previous work. The problem was easily fixed, and the corrected result was presented. This experience spurred the PI to examine in detail this subtle problem about masking. In January 2009, the PI wrote an article about this problem and posted it on the IACR ePrint site, along with a corrected version of the paper.

Careful hardware implementation of this masked S-box should provide added security to encryption for applications such as smart cards, where circuitry is extremely limited.

PUBLICATION:


REPORTS:


KEYWORDS: Cryptography, AES, Rijndael, S-Box, Masking

ASTRODYNAMICS RESEARCH - 2008
Donald A. Danielson, Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: To apply astrodynamics theory to problems of interest to the military.

SUMMARY: On 30-31 January, Professor Danielson hosted Dr. Steve Knowles, Space Operations Analyst for the Science Applications International Corporation. Dr. Knowles was at the Naval Postgraduate School to deliver the SS4000 seminar “Anti-Satellite Weapons – Kinematics of Intercept” and to discuss joint research with Professor Danielson in the orbital dynamics area. Professor Danielson’s former Master’s student, LTC Pat Marshall, is working with Dr. Knowles on a Ph.D. thesis in aerospace engineering.

Professor Danielson’s 1995 report documenting the Semianalytic Satellite Theory has received a lot of attention in the aerospace world. He made the only complete documentation of the code, used at Draper Labs, which is much faster (but just as accurate) than a brute-force numerical solution of the differential equations. Since its publication, he has received many requests for this report and questions about it. He also discovered an error in the code, which was corrected and resulted in improved orbit predictions. In 2008, he was notified that the Analytical Graphics Corporation is incorporating the code into Satellite Tool Kit, which is the market-leading satellite orbit predicting software. Professor Danielson’s report and conversations with the orbital engineers are a big part of their knowledge base.
SECURELY IMPLEMENTING THE ADVANCED ENCRYPTION STANDARD ON A CELLBE MULTI-PROCESSOR

George W. Dinolt, Associate Professor
Simson L. Garfinkel, Associate Professor
Jonathon C. Herzog, Associate Professor
Bruce Allen, Research Associate
Department of Computer Science
David Canright, Associate Professor
Department of Applied Mathematics
Sponsor: National Security Agency

OBJECTIVE: To explore security issues in developing a high-speed implementation of the Advanced Encryption Standard (AES) on the “Cell Broadband Engine” (CellBE) multi-processor chip.

SUMMARY: The sponsor has some interest in the CellBE chip from IBM, which incorporates a Power-PC processor and eight “Synergistic Processor Elements.” All nine processors use a Single-Instruction-Multiple-Data (SIMD) instruction set (the SPEs use a different SIMD instruction set from the PPC). This chip is at the heart of the Sony PlayStation-3 gaming console, where the multi-processor architecture allows fast graphics rendering, etc.

IBM has a proprietary implementation of AES on the CellBE that achieves high throughput. In 2008, the principal investigator (PI) developed a high-speed AES implementation, written directly in the SPE assembly language. This encryptor was integrated into this implementation of Galois Counter Mode (GCM), which combines parallelizable encryption (counter mode) with hashing (using Galois multiplication) to authenticate message integrity through a message tag. (The PI also developed SPE assembly implementations of the Galois hash function, as well as the associated table setup and the AES key schedule.)

The PI continued to refine the AES implementation and managed to get it faster than the IBM benchmark in January 2009. The PI wrote a technical report on the development of this AES implementation, which will be submitted to the NPS Research Office in February 2009.

KEYWORDS: CellBE, Cryptography, AES, Galois Counter Mode

DIRECT IMAGING OF ANISOTROPIC MINORITY-CARRIER DIFFUSION IN ORDERED GAINP

Christopher L. Frenzen, Associate Professor
Clyde Scandrett, Professor
Department of Applied Mathematics
Nancy M. Haegel, Distinguished Professor
T.J. Mills,
M. Talmadge,
Department of Physics
H. Yoon, SpectroLabs, Inc.
C.M. Fetzer, SpectroLabs, Inc.
R.R. King, SpectroLabs, Inc.
Sponsor: Unfunded

OBJECTIVE: To find an all-optical technique to provide the first direct measurement of anisotropic minority-carrier diffusion in an ordered alloy of GainP.

SUMMARY: An all-optical technique to provide the first direct measurement of anisotropic minority-carrier diffusion in an ordered alloy of GainP was developed. Direct imaging of the minority-carrier diffusion distribution resulting from generation at a quasi-point source was obtained using an optical microscope coupled to a scanning electron microscope. This measurement provides a key parameter of interest to the performance of state-of-the-art triple junction solar cells.
PUBLICATION:

**PROOF WITHOUT WORDS: ORDERING THE ARITHMETIC, GEOMETRIC, AND HARMONIC MEANS**
Christopher L. Frenzen, Associate Professor
Department of Applied Mathematics
Sponsor: Unfunded

**OBJECTIVE:** Can one provide a proof, visually without words, of the ordering of the fundamental means – the arithmetic, geometric, and harmonic? This was the objective of this work.

**SUMMARY:** A proof without words is given which shows, at a glance, that the fundamental ordering of the three most common means is: the harmonic mean $H(a,b)$ is less than or equal to the geometric mean $G(a,b)$ is less than or equal to the arithmetic mean $A(a,b)$, with equality in all nontrivial cases if and only if $a = b$.

**PUBLICATION:**

**AN ALLIANCE PARTITION NUMBER IN GRAPHS**
Ralucca Gera, Assistant Professor
Department of Applied Mathematics
Linda Eroh, Department of Applied Mathematics
University of Wisconsin-Oshkosh
Sponsor: RIP

**OBJECTIVE:** Let $G$ be a graph with vertex set $V(G)$ and edge set $E(G)$. A (defensive) alliance in $G$ is a subset $S$ of $V(G)$ such that for every vertex $v \in S$, $|N[v] \cap S| \geq |N(v) \cap (V(G) - S)|$. The alliance partition number of a graph $G$, $\psi_a(G)$, is defined to be the maximum number of sets in a partition of $V(G)$ such that each set is a (defensive) alliance. In this paper, both general bounds and exact results for the alliance partition number of graphs are given, in particular for regular graphs and trees.

**KEYWORDS:** Alliance, Regular Graphs

**THE EXTENSION OF STRONGLY REGULAR GRAPHS**
Ralucca Gera, Assistant Professor
Department of Applied Mathematics
Jian Shen, Department of Applied Mathematics
Texas State University
Sponsor: Unfunded

**OBJECTIVE:** The Friendship Theorem states that if any two people in a party have exactly one common friend, then there exists a politician who is friend of everybody. In this paper, the Friendship Theorem is generalized. Let $\lambda$ be any non-negative integer and $\mu$ be any positive integer. Suppose each pair of friends have exactly $\lambda$ common friends and each pair of strangers have exactly $\mu$ common friends in a party. (The corresponding graph is a generalization of strongly regular graphs by relaxing the regularity property on vertex degrees.) It was proven that either everyone has the exact same number of friends or there exists a
politician who is a friend of everybody. As an immediate consequence, this implies a recent conjecture by Limaye, et al.

KEYWORDS: Strongly Regular Graphs

GEODESIC DOMINATION IN GRAPHS
Ralucca Gera, Assistant Professor
Department of Applied Mathematics
Henry Escuadro, Department of Mathematics
Juniata College
N. Jafari Rad, Department of Applied Mathematics
Shahrood University of Technology
Sponsor: Unfunded

OBJECTIVE: For vertices x and y in a connected graph G, the distance d(x, y) is the length of a shortest x − y path in G. An x − y path of length d(x, y) is called an x − y geodesic. A vertex v is said to lie in an x − y geodesic P if v is an internal vertex of P. The closed interval I[x, y] consists of x, y and all vertices lying in some x − y geodesic of G, while for S ⊆ V (G), I[S]= ∪x,y∈Si[x, y].

A set S of vertices is a geodetic set if I[S]= V (G) A subset S of vertices in a graph G is a geodesic dominating set if S is both a geodetic and a standard dominating set. In this paper, geodesic domination in a graph G is studied.

KEYWORDS: Domination, Geodesic, Geodetic

GLOBAL ALLIANCE PARTITION IN TREES
Ralucca Gera, Assistant Professor
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Linda Eroh, Department of Applied Mathematics
University of Wisconsin-Oshkosh
Sponsor: RIP

OBJECTIVE: Let G be a connected graph with vertex set V (G) and edge set E(G). A (defensive) alliance in G is a subset S of V (G) such that for every vertex v ∈ S, |N[v] ∩ S|≥|N(v) ∩ (V (G) − S)|. The alliance partition number, ψa(G), is defined to be the maximum number of sets in a partition of V (G) such that each set is a (defensive) alliance. Similarly, ψg(G) is the maximum number of sets in a partition of V (G) such that each set is a global alliance, i.e., each set is an alliance and a dominating set. In this paper, bounds are given for the global alliance partition number in terms of the minimum degree, which gives exactly two values for ψg(G) in trees. This research concentrates on conditions that classify trees to have ψg(G)= i (i =1, 2), presenting a characterization for binary trees.

KEYWORDS: Alliance, Global Alliance, Domination, Partition, Alliance Partition
THE INDEPENDENCE NUMBER FOR GENERALIZED PETERSEN GRAPHS
Ralucca Gera, Assistant Professor
Pantelimon Stanica, Associate Professor
Department of Applied Mathematics
Joseph Fox, Salem State College
Sponsor: RIP

SUMMARY: Given a graph G, an independent set I(G) is a subset of the vertices of G such that no two vertices in I(G) are adjacent. The independence number \( \alpha(G) \) is the order of a largest set of independent vertices. In this paper, the independence number for Generalized Petersen graphs was studied, finding both sharp bounds and exact results for subclasses of Generalized Petersen graphs.

KEYWORDS: Independence, Petersen Graph

SPECTRAL THEORY AND D-INDEPENDENCE NUMBERS FOR HYPERCUBES AND SOME GENERALIZED PETERSEN GRAPHS
Ralucca Gera, Assistant Professor
Pantelimon Stanica, Associate Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: Given a graph G, an independent set I(G) is a subset of the vertices of G such that no two vertices in I(G) are adjacent. The independence number \( \alpha(G) \) is the order of a largest set of independent vertices. A generalization of this is the packing number. A subset I(G) is a d-packing if \( \forall x, y \in I(G) \), we have that \( d(x, y) > d \). We study the spectrum and d-packing number for the hypercube and the generalized Petersen graph \( P(n, 2) \).

KEYWORDS: Packing Number, Regular Graphs, Hypercube, Generalized Petersen Graph, Eigenvalues, Distance Independence

VERTEX AND EDGE-CRITICAL TOTAL RESTRAINED DOMINATION IN GRAPHS
Ralucca Gera, Assistant Professor
J.H. Hattingh, Department of Applied Mathematics and Statistics
Georgia State University
N. Jafari Rad, Department of Applied Mathematics
Shahrood University of Technology
E.J. Joubert, Department of Applied Mathematics
University of Johannesburg
Sponsor: Unfunded

OBJECTIVE: The removal of a vertex in a graph may decrease the domination number. A graph G is called vertex domination critical if \( \gamma(G - v) < \gamma(G) \), for every vertex v in G. A graph G with no isolated vertices is total restrained domination vertex critical if for any vertex v of G that is not adjacent to a vertex of degree one, the total restrained domination number of \( G - v \) is less than the total restrained domination number of G. These graphs are called \( \gamma_{tr} \)-critical. If such a graph G has total restrained domination number k, it is called \( k - \gamma_{tr} \)-critical. In this paper, \( \gamma_{tr} \)-critical graphs are studied and \( \gamma_{tr} \)-critical trees are characterized. An upper bound on the diameter of a connected \( k - \gamma_{tr} \)-critical graph is then established.

KEYWORDS: Restrained Domination, Domination Critical
THE DEVELOPMENT OF A HIGH-ORDER, DISCONTINUOUS GALERKIN OCEAN MODEL
Francis X. Giraldo, Associate Professor
Department of Applied Mathematics
Sponsor: RIP

OBJECTIVE: The U.S. Navy currently uses a finite element model on linear, triangular grids. However, this model does not conserve mass because it uses a generalized-wave-continuity equation in order to avoid the well-known Inf-Sup condition. To avoid both of these issues, the research team proposed to use high-order, discontinuous Galerkin methods on unstructured, triangular grids. This will result in a fully conservative model, high-order accurate, and highly scalable on distributed-memory computers. In addition, the research team extends the explicit time-integration to semi-implicit adaptive time-stepping, allowing for much flexibility in the size of the time-steps for integrating the model forward in time.

PUBLICATIONS:


THESIS DIRECTED:

KEYWORDS: Discontinuous Galerkin, Slope Limiters, Shallow Water, Tsunami Modeling

NEXT-GENERATION GLOBAL AND MESOSCALE, NONHYDROSTATIC, ATMOSPHERIC MODELS
Francis X. Giraldo, Associate Professor
Department of Applied Mathematics
Sponsor: Office of Naval Research (Battle Space Environments)

OBJECTIVE: The U.S. Navy would like to replace their existing second-order finite-difference model, which relies on leapfrog time-stepping and split-explicit algorithms to by-pass the time-step restriction caused by vertically propagating acoustic waves. To this end, the research team proposes to develop spectral element and discontinuous Galerkin methods that are high-order accurate, conserve all variables, permit the use of unstructured adaptive grids, and scale extremely well on distributed-memory computers. In addition, it is proposed to use a different form of the governing equations for these models, the fully compressible Navier-Stokes equations. To by-pass the time-step restriction, it is proposed to develop semi-implicit time-integrators.

PUBLICATIONS:


**CONFERENCE PRESENTATIONS:**


**THESES DIRECTED:**


**KEYWORDS:** Discontinuous Galerkin, Euler Equations, Navier-Stokes, Spectral Element, Implicit Methods

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**DATA ASSIMILATION USING PSEUDOSPECTRAL OPTIMAL CONTROL**

Wei Kang, Professor

*Department of Applied Mathematics*

*Sponsor: Naval Research Laboratory*

**OBJECTIVE:** To explore the potential and advantage of applying the state-of-the-art in optimal control theory to the problem of data assimilation.

**SUMMARY:** This research focused on the application of pseudospectral (PS) optimal control to the problem of data assimilation subject to nonlinear dynamics. The goal is to develop discretization methods based upon PS optimal control that use fewer nodes than conventional approaches, which implies a relatively lower dimension in the discretized nonlinear optimization.

**PUBLICATION:**

APPLIED MATHEMATICS

PSEUDOSPECTRAL OPTIMAL CONTROL OF NONLINEAR SYSTEMS
Wei Kang, Professor
Department of Applied Mathematics
I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering
Sponsor: AFOSR

OBJECTIVE: To develop practical methods to solve highly nonlinear, optimal-control problems, and to prove the efficiency of the methods by proving the feasibility and convergence. The fundamental concept in the approach is based on the Pseudospectral Approximation Theory of Numerical Computation and nonlinear programming for complicated optimization problems.

SUMMARY: For some important families of nonlinear systems, the feasibility and convergence of the pseudospectral optimal-control method were proved. In addition, the Covector Mapping Theorem, an important result that bridges the optimal state in a control system with the necessary conditions of optimal control, was proved for general nonlinear systems. In 2007 and 2008, several new theorems were proved on convergence with significantly simplified and reduced the assumptions relative to the theorems proved in 2006. In addition, the convergence results were generalized to problems with discontinuous optimal control.

PUBLICATIONS:


CONFERENCE PUBLICATION:


PRESENTATION:


BOOK:


SENSOR TO COMMANDER METRICS
Wei Kang, Professor
Department of Applied Mathematics
Sponsor: TRADOC-ARO

OBJECTIVE: To develop models for complex information flow and information processing networks for battlefield applications.
SUMMARY: Developed a deterministic, discrete, dynamical system model which depicts information flow between Ovals 2 and 3 of the Dynamic Model of Situated Cognition; enhanced this model by incorporating stochastic inputs by modeling information-package arrival times and required processing times as random variables; defined Total Information Volume as a useful and relevant metric; and performed an initial validation of the model using data produced during a Defense Advanced Research Projects Agency command and control experiment, with reasonable results.

DISSERTATION DIRECTED:


SENSOR TO COMMANDER METRICS
Wei Kang, Professor
Department of Applied Mathematics
Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To develop models for complex information flow and information processing networks for battlefield applications. Given the complexity of this problem, new theory and algorithms must be developed; this is the step of research in which some essential difficulties and challenges that call for innovative ideas and approaches must be faced. In addition, simulations will be carried out to verify the model being developed.

SENSOR TO COMMANDER METRICS
Wei Kang, Professor
Department of Applied Mathematics
Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To develop mathematical theory and computational algorithms for the optimal control of information flow. Given the complexity of this problem, no existing methodologies or algorithms can satisfactorily solve the optimal control problem. Therefore, new theory and algorithms must be developed. This is the step of research in which some essential difficulties and challenges that call for innovative ideas and approaches must be faced. In addition, simulations will be carried out for

ASTRODYNAMICS
Beny Neta, Professor
Department of Applied Mathematics
Sponsor: Naval Postgraduate School

SUMMARY: The principal investigator is a member of the AIAA, Astrodynamics Technical Committee. The PI served as the technical co-chair of the 18th AAS/AIAA Space Flight Mechanics Meeting in Galveston, Texas, from 27-31 January 2008. The proceedings of this meeting were published.

PUBLICATION:

SUMMARY: One of the most important problems in numerical analysis is the solution of nonlinear equations $F(x) = 0$. One can use iterative methods to solve these equations. There are many schemes for obtaining simple roots of nonlinear equations. This work extends such methods to the case of roots with multiplicity greater than one, and also finds more efficient schemes for simple roots. This work was done jointly with a former student of the Mathematics Department (Dr. A.N. Johnson, USMA) and Professor C. Chun, Sungkyunkwan University, Republic of Korea.

PUBLICATIONS:


KEYWORDS: Nonlinear Equations, High Order, Multiple Roots, Efficiency
work was performed in conjunction with Professors Temur Jangveladze and Zurab Kiguradze of Ivane Javakhishvili Tbilisi State University and Ilia Chavchavadze State University, Tbilisi, Georgia. Professor Kiguradze spent three months at the Naval Postgraduate School during April-June 2008.

PUBLICATIONS:


CONFERENCE PUBLICATIONS:


A STUDY OF NON-REFLECTING BOUNDARY CONDITIONS
Beny Neta, Professor
Department of Applied Mathematics
Sponsor: Naval Postgraduate School

OBJECTIVE: The implementation of high-order non-reflecting boundary conditions. The model used was the linearized 2-D Euler equation. These equations were solved by the finite difference method.

PUBLICATIONS:


THESIS DIRECTED:


KEYWORDS: Euler Equations, Non-Reflecting Boundary Conditions
GAME-THEORETIC APPROACHES TO TERRORIST AND INSURGENT NETWORKS
Guillermo Owen, Professor
Department of Applied Mathematics
Sponsor: Department of Defense Analysis

OBJECTIVE: This project is funded through the Department of Defense Analysis. Professor Owen and Professor Gordon McCormick of the Department of Defense Analysis are co-principal investigators.

PUBLICATIONS:


MATHEMATICAL MODELS OF SEARCH
Guillermo Owen, Professor
Department of Applied Mathematics
Sponsor: Department of Defense Analysis

OBJECTIVE: This project is funded through the Department of Defense Analysis. Professor Owen and Professor Gordon McCormick of the Department of Defense Analysis are co-principal investigators. They have developed game-theoretic models for search and published one article on this topic.

PUBLICATION:


A THEORY OF GAMES AND APPLICATIONS
Guillermo Owen, Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: This is an unsponsored project, on which Professor Owen has worked with mathematicians at the University of Caen, France; the Complutense University in Madrid, Spain; the Polytechnic University of Catalonia, Terrassa, Spain; and at the Universities of Tilburg and of Amsterdam, Netherlands.

PUBLICATIONS:


**PRESENTATIONS:**


**SET COLORINGS IN GRAPHS**

Craig Rasmussen, Associate Professor
Department of Applied Mathematics
Sponsor: NPS Workload Reduction (H) Funds

**OBJECTIVE:** A new graph parameter called the set chromatic number is examined. The initial goal is to find bounds and/or exact values of the set chromatic number of a graph in terms of familiar graph parameters.

**SUMMARY:** This is new work, begun in 2008 with Gary Chartrand and Ping Zhang of Western Michigan University and Futaba Okamoto of the University of Wisconsin at LaCrosse. The work continues in 2009, with Raluca Gera of the Naval Postgraduate School joining the effort. A set coloring in a nontrivial connected graph G=(V,E) is defined as follows: the map c, from V to the natural numbers, is a vertex coloring in which adjacent vertices might receive the same color. For a vertex v in V, the neighborhood color set NC(v) is the set of colors assigned to the neighbors of v. The coloring is called a set coloring if NC(u) disagrees with NC(v) for every edge e = {u,v} in E. The minimum number of colors required of
such a coloring is called the set chromatic number, denoted \( \chi_s(G) \). The initial work was focused on determining the set chromatic numbers of some well-known classes of graphs and on finding bounds on the set chromatic number of an arbitrary graph \( G \) in terms of more familiar graph parameters. From this initial effort, the principal investigators proceeded to investigate the set chromatic numbers of joins of the join \( G+H \) of two graphs \( G \) and \( H \). Sharp lower and upper bounds were established for \( \chi_s(G + H) \) in terms of \( \chi_s(G), \chi_s(H), \) and the clique numbers \( \omega(G) \) and \( \omega(H) \). Recent work has focused on the complexity of computing the set chromatic number, on the set chromatic numbers of certain classes of perfect graphs, and on Nordhaus-Gaddum-type inequalities for the set chromatic number. Two journal articles were accepted for publication in 2008.

**PUBLICATIONS:**


**KEYWORDS:** Set Coloring, NP-Completeness, Chromatic Number

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**HYDROGEN STORAGE EMPLOYING CARBON NANOSTRUCTURES**

Clyde Scandrett, Professor  
Department of Applied Mathematics  
John Lloyd, Professor  
Department of Mechanical and Astronautical Engineering  
Sponsor: Unfunded

**OBJECTIVE:** To examine the feasibility and perform modeling of carbon nanostructures for the purpose of meeting the USDOE 2010 goal for fuel tank storage capacity of 6.5%wt hydrogen.

**SUMMARY:** Employing a general-purpose molecular-dynamics code, the General Utility Lattice Program (GULP), models of hydrogen molecules adsorption to graphene and carbon nanotubes were run on a high-performance cluster at the Naval Postgraduate School. A particular sandwich structure was investigated and is under further consideration as patentable.

**PATENT:** Preliminaries for a patent on the geometry developed are being processed.


**KEYWORDS:** Hydrogen Storage Devices, LJ Potentials, Brenner Potentials, Molecular Dynamics

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**A MINE WARFARE SYMPOSIUM**

Clyde Scandrett, Professor  
Department of Applied Mathematics  
Sponsor: Naval Postgraduate School, Office of Naval Research

**OBJECTIVE:** To host the Eighth Bi-Annual Symposium on Technology and Sponsored Programs Related to Mine Warfare. The symposium was held at the Naval Postgraduate School from 6-8 May 2008.
APPLIED MATHEMATICS

SUMMARY: The funds helped support the planning and execution of a technical symposium on mines. The purpose of the symposium was to continue the examination of the potentials of emergent technologies to enhance the capabilities of the U.S. and its allies in mining, mine countermeasures, and humanitarian demining, including area remediation. The themes of the symposium were technologies for mine warfare, expeditionary warfare, and harbor protection/port security. As with the seven preceding symposia, this symposium was a joint undertaking of several U.S. government agencies.

PUBLICATION:


KEYWORDS: Mines, Mining, Undersea Warfare

MODELING OF SEMICONDUCTOR MINORITY-CARRIER DIFFUSION
Clyde Scandrett, Professor
Christopher L. Frenzen, Associate Professor
Department of Applied Mathematics
Nancy M. Haegel, Distinguished Professor
Department of Physics
Sponsor: Unfunded

OBJECTIVE: To collaborate with experimentalists using an optical microscope coupled with a scanning electron microscope, producing images that can be modeled numerically to determine characteristics of double heterostructures. Mathematical modeling of experimental results should ascertain key parameters of interest to the performance of state-of-the-art triple junction solar cells.

SUMMARY: Point-source and line-source experimental results have been obtained and modeled in the determination of diffusion lengths for a variety of semiconductors. Excellent fits between experimental and mathematically modeled results have encouraged further work in the area, leading to the submission of a paper and continued thesis advising of students in the Applied Physics curriculum at the Naval Postgraduate School.

PUBLICATION:


THESIS ADVISED:


KEYWORDS: Semiconductors, Solar Cells

BALANCED SYMMETRIC BOOLEAN FUNCTIONS IN FINITE FIELDS
Pantelimon Stanica, Associate Professor
Department of Applied Mathematics
Thomas W. Cusick, Professor
State University of New York at Buffalo
Y. Li, Alcorn State University
Sponsor: Naval Postgraduate School, Research Initiation Program

OBJECTIVE: To count and characterize symmetric Boolean functions.
SUMMARY: Balancedness is a desirable requirement of functions that are to be used in cryptography. In this project, Stanica and his collaborators give a lower bound for the number of balanced symmetric polynomials over GF($p$), and as an immediate consequence, they show the existence of nonlinear, balanced symmetric polynomials. The work has proven to be quite difficult. There was only one case uncovered in the entire investigation; if that is done, it will probably be a significant advancement in the area.

PUBLICATIONS:


PRESENTATION:


KEYWORDS: Cryptography, Symmetry, Balancedness, Boolean Functions

BINAR Y AND Q-ARY EXPANSIONS

Pantelimon Stanica, Associate Professor
Hal Fredricksen, Professor
Department of Applied Mathematics
Eugen J. Ionascu, Professor
Columbus State University
Florian Luca, Research Professor
Universidad Nacional Autónoma de México
Cecile Dartyge, Professor
L’Institut Élie Cartan, Université Henri Poincaré–Nancy, France
Sponsor: Unfunded

OBJECTIVE: To investigate representations of integers in various bases.

SUMMARY: A $q$-Niven number is an integer $k$ which is divisible by the sum of its base $q$ digits. In this paper, a natural sequence in relation to $q$-Niven numbers is defined. For a fixed but arbitrary integer $k$ and a base $q$, one may ask whether or not there exists a $q$-Niven number $n$ whose sum of digits $s_q(n)$ is precisely $k$. In this project [1] it was shown that the answer is affirmative. In [2] all representations of a transcendental number using certain trigonometric functions of rational numbers were found. Let $q>1$ be an integer and $s_q(m)$ be the sum of digits in base $q$ of the positive integer $m$. In [3] the positive integers $n$ such that $s_q(n)$ and $s_q(kn)$ satisfy certain relations for a fixed, or arbitrary positive integer $k$, were studied, solving some open problems proposed by other researchers.

PUBLICATIONS:


PRESENTATIONS:


KEYWORDS: Arithmetical Functions, Representations, Number Theory

CRYPTOGRAPHIC BOOLEAN FUNCTIONS

Pantelimon Stanica, Associate Professor
Department of Applied Mathematics
Jon T. Butler, Professor
Department of Electrical and Computer Engineering
S. Maitra, Indian Statistical Institute
Sponsor: AFOSR-QDR and the Naval Postgraduate School, Research Initiation Program

OBJECTIVE: To investigate cryptographic properties of Boolean functions.

SUMMARY: In this project the principal investigator (PI) found some conditions for the non-existence of bent Boolean functions that are symmetric under a group of permutations. In a related project with S. Maitra, the exact count and various cryptographic properties of rotation symmetric functions were found. Some of these ideas were used in a grant proposal submission to the NSA. A connected proposal was submitted to and funded by AFOSR-QDR. The PI and Professor Jon Butler supervised three students’ Master’s theses based on problems in this area.

PUBLICATIONS:


KEYWORDS: Cryptography, Boolean Functions

INVESTIGATIONS ON NUMBER FIELD SIEVE

Pantelimon Stanica, Associate Professor
Department of Applied Mathematics
S. Maitra, Indian Statistical Institute
Y.V. Subba Rao, Indian Statistical Institute
S. Gangopadhyay, Indian Statistical Institute
Sponsor: Unfunded

OBJECTIVE: Improvements on discrete logs and factorization algorithms used in public-key cryptography.

SUMMARY: The goal of this project was to investigate a not-so-well-known side of a precursor of the general number field sieve (GNFS), namely, the cubic sieve congruence (CSC) problem. Given a prime number p, nontrivial solutions to the CSC, x^3=y^2z (mod p) (non-equal and x,y,z<p^(1/2)) and useful in solving the Discrete Logarithm or factorization by index calculus methods. Apart from the cryptographic interest, the problem was intriguing from a number theoretical point of view. Certain classes of primes
were identified where the problem can be solved in polynomial time (oftentimes in constant time). Designers of cryptosystems should avoid all primes in the detected classes.

**PUBLICATION:**

Maitra, S., Subba Rao, Y.V., Stanica, P., and Gangopadhyay, S., “Nontrivial Solutions to the Cubic Sieve Congruence Problem $x^3 = y^2 z \pmod{p}$,” *Journal of Computacion y Sistemas, Special Issue on Applied Cryptography and Data Security* (accepted).

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**“LACED” BOOLEAN FUNCTIONS**

Pantelimon Stanica, Associate Professor  
David Canright, Associate Professor  
Department of Applied Mathematics  
Sponsor: Unfunded

**OBJECTIVE:** To investigate a certain family of Boolean functions of recent interest in the literature.

**SUMMARY:** Previous work related to read-once branching programs led to the definition of a special Boolean function based on weighted sums in $\mathbb{Z}_p$, for prime $p$.

The principal investigators (PI), with colleagues in India, investigated this function and a slight variant thereof, in terms of weight, sensitivity, and other properties. Professor Canright’s contribution included computer programs (using Maple and/or C) to directly compute weight and sensitivity, some small proofs, and a way to get a formula for the sensitivity in one special case; Professor Stanica did all the heavy lifting, notably including computing simple, closed-form formulas from complicated, multiple sums.

**PUBLICATION:**


**KEYWORDS:** Boolean Functions, Hamming Weight, Subset Sum Problems

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**LINEAR ALGEBRA METHODS IN NUMBER THEORY**

Pantelimon Stanica, Associate Professor  
Department of Applied Mathematics  
Emrah Kilic, TOBB  
Department of Applied Mathematics, Turkey  
Sponsor: Naval Postgraduate School, Research Initiation Program

**OBJECTIVE:** Special matrices and their algebraic properties.

**SUMMARY:** Tridiagonal matrices are used in telecommunication system analysis, finite difference methods for solving PDEs, linear recurrence systems with non-constant coefficients, etc. Therefore, it should be of interest to find ways to compute the inverse of general banded matrices. In the current investigation, previous work was extended on computing the inverse of a lower triangular or tridiagonal matrix to banded matrices. As a special case, Toeplitz matrices were mentioned. Many existing results were obtained as straightforward corollaries of this work.

**PUBLICATIONS:**


CONFERENCE PUBLICATION:


PRESENTATIONS:


KEYWORDS: Binary Sequences, Representations, Linear Algebra, Combinatorics

PROPERTIES OF THE THUE-MORSE SEQUENCE

Pantelimon Stanica, Associate Professor
Department of Applied Mathematics
Thomas W. Cusick, Professor
State University of New York at Buffalo
Sponsor: Unfunded

OBJECTIVE: To investigate the structure of the Thue-Morse sequence through the prism of Boolean functions.

SUMMARY: The goal of the project was to investigate the Thue-Morse sequence over arithmetic progressions. The tools were taken from Boolean functions research. Similar techniques were needed to show some conjectures on the Hamming weights of integers sitting in arithmetic progressions.

PUBLICATIONS:


KEYWORDS: Sequences, Representations, Combinatorics

SPECTRAL PROBLEMS IN SPECIAL GRAPHS

Pantelimon Stanica, Associate Professor
Ralucca Gera, Assistant Professor
Department of Applied Mathematics
Sponsor: Unfunded

OBJECTIVE: To investigate the spectra of various graphs.

SUMMARY: Given a graph $G$, an independent set $I(G)$ is a subset of the vertices of $G$ such that no two vertices in $I(G)$ are adjacent. A generalization of this is a $d$-packing. A subset $I(G)$ in $V(G)$ is a $d$-packing if for all $x, y$ in $I(G)$, we have that $d(x,y) > d$. In this project, the spectrum and $d$-packing number for the hypercube and the generalized Petersen graph $P(n,2)$ were studied.
APPLIED MATHEMATICS

PUBLICATION:


KEYWORDS: Graph Theory, Labelings, Minimization, Independence, Petersen Graphs

MATHEMATICAL STUDIES OF COMPLEX FLUIDS

Hong Zhou, Associate Professor
Department of Applied Mathematics
Sponsor: AFOSR

OBJECTIVE: To study the extendability of equilibrium states of rodlike nematic polymers with the Maier-Saupe intermolecular potential, and thus to establish the existence and uniqueness of equilibrium states in the presence of small perturbations away from equilibrium states; 2) to apply the nonlinear geometric control theory to examine the controllability of various complex materials with imposed simple flows; and 3) to consider an optimization problem in thermoelectric cooling and solve it exactly.

SUMMARY: Nematic liquid-crystalline polymers and nanocomposites have wide-ranging applications in Air Force and Navy products. The long-term goal of this research is to build a solid theoretical foundation towards a complete understanding of the performance features of these materials and to provide a guideline for developing future materials for the Navy and the Air Force. Preliminary results on the controllability of complex fluids may eventually shed light on how to obtain materials with desired properties by proper control.

PUBLICATIONS:


PRESENTATIONS:


DEPARTMENT OF
APPLIED MATHEMATICS

2008
Faculty Publications
and Presentations


PREsentations


BOOK


REPORTS


DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

JEFFREY B. KNORR
CHAIR
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 are grouped into ten major areas of emphasis that support the curricula served by the department and Department of Defense plans. Unique to the ECE Department and NPS 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, our curricula and courses will remain at the cutting edge, we can recruit and retain quality faculty, and 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
- Systems Engineering

DEGREES GRANTED:

- Master of Science in Electrical Engineering
- Master of Science in Engineering Science
- Electrical Engineer
- Doctor of Philosophy

RESEARCH THRUST AREAS:

- Communications and Signal Processing
- Electric Power and Control
- Network Engineering
- Sensor Systems Engineering
- Computers and Microelectronics

LABORATORIES:

- Nano-Electronics Laboratory
- Circuits, Signals, and Digital Systems Laboratory
- Academic Computing Laboratory
- Microwave and Antenna Laboratory
- Radar and Electronic-Warfare Systems Laboratory
- Controls and Robotics Laboratory
- Power Systems Laboratory
- Digital Signal Processing Laboratory
- Computer Communications and Networking Laboratory
- Secure Computing Laboratory
- Cryptologic Research Laboratory
• Signal Enhancement Laboratory

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)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include 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:

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DEPARTMENT OF
ELECTRICAL AND
COMPUTER ENGINEERING

2008
Faculty Publications
and Presentations
DEPARTMENT OF
MECHANICAL AND
ASTRONAUTICAL
ENGINEERING

ANTHONY J. HEALEY
CHAIR
OVERVIEW:

The Department of Mechanical and Astronautical Engineering (MAE) provides a strong academic program that spans the engineering disciplines of thermal-fluid sciences, structural mechanics, dynamic systems, guidance and control, materials science and engineering, propulsion, and systems engineering, including total ship systems engineering, spacecraft, and missile design. These disciplines are blended together with a strong emphasis on naval engineering applications required by surface vessels, submarines, and spacecraft. Furthermore, the department provides advanced education in classified topics in astronautical engineering. Programs leading to the degree of Master of Science in Mechanical Engineering or Master of Science in Astronautical Engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). A specific curriculum must be consistent with the general minimum requirements for the degree as determined by the academic council. Any program leading to a degree must be approved by the department chair at least two quarters before completion. In general, approved programs will require more than the stated minimum degree requirements in order to conform to the needs and objectives of the United States Navy and satisfy the applicable subspecialty-code requirements.

RESEARCH MISSION:

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, spanning the field from basic phenomena to engineering design, development, operation, maintenance, and disposal of components and systems for naval platforms.

CURRICULA SERVED:

The MAE Department serves the Naval and Mechanical-Engineering curriculum (570), the Mechanical-and Reactors-Engineering curriculum (571), and the Space-Systems Engineering curriculum (591). These curricula support the Navy’s need for individuals with advanced technical education in mechanical and astronautical 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 to have the ability to identify, formulate, and solve technical and engineering problems in areas related to mechanical engineering. The Space-Systems Engineering program provides officers with a comprehensive, scientific, and technical knowledge of national security, military, and naval space-systems.

DEGREES GRANTED:

- Master of Science in Mechanical Engineering
- Master of Science in Astronautical Engineering
- Mechanical Engineer
- Astronautical Engineer
- Doctor of Philosophy
- Doctor of Engineering

RESEARCH THRUSTS:

- Fluid Dynamics, Heat Transfer, and Turbomachinery
- Dynamic Systems, Controls, and Robotics
- Solid Mechanics, Vibrations, and Shock
- Materials Science and Engineering
- Space-Systems
• Total Ship Systems Engineering

FACULTY EXPERTISE:

• Fluid Dynamics, Heat Transfer, and Turbomachinery:
  Professor Knox Millsaps, Jr., Associate Professor Ashok Gopinath, Professor Garth Hobson

• Dynamic Systems, Controls, and Robotics:
  Distinguished Professor Brij Agrawal, Distinguished Professor Anthony Healey, Professor Morris Driels, Professor Issac Kaminer, Associate Professor Fotis Papoulias, Assistant Professor Marcello Romano, Professor I. Michael Ross

• Solid Mechanics, Vibration, and Shock:
  Professor Young Shin, Professor Young W. Kwon

• Materials Science and Engineering:
  Professor Terry McNelley, Professor Indranath Dutta

• Space-Systems:
  Distinguished Professor Brij Agrawal, Professor Issac Kaminer, Assistant Professor Marcello Romano, Professor I. Michael Ross

• Total Ship Systems Engineering:
  Associate Professor Fotis Papoulias

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)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Mechanical and Astronautical Engineering is provided below.
Size of Program: $5.1M
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EXPERT SUPPORT FOR UNSTEADY FLOW-CONTROL EXPERIMENTS/DYNAMIC STALL UNSTEADY FLOW EXPERIMENTS

Muguru S. Chandrasekhara, Research Professor
Department of Mechanical and Astronautical Engineering
Sponsor: U.S. Army Aeroflightdynamics Directorate

OBJECTIVE: To support ongoing experimental, unsteady flow-control research related to dynamic stall and helicopter rotor separation control through devising advanced measurement techniques and instrumentation.

SUMMARY: During the year, the custom particle image velocimetry (PIV) system that was specifically configured and ordered for this project was delivered. It was assembled with the aid of an AFDD contractor. Then, a series of validation tests was run on the unit. The system optics can be set up as either a standard PIV system or as a telescopic-PIV system. Measurements were carried out using both arrangements. Initial experiments yielded unacceptably large differences in the measured velocity values between the two.

This led to an imperative need to conduct measurements in well-known flows for which the velocities can also be theoretically established. For this, a hot-wire anemometer calibrator jet was used and measurements were made in the jet potential core. Also, the data analysis method was altered to use progressively smaller interrogation windows in the PIV images until invariant and reliable velocity values were obtained. A 12 x 12 pixel interrogation window provided satisfied results, pointing to the software from the vendor as being too permissive. Now, additional validation tests in flat plate boundary layers and in cases using synthetic blowing flow control will be conducted to further validate the system.

PUBLICATION:

PRESENTATION:

MISSILE AERODYNAMICS PREDICTION STUDIES

Muguru S. Chandrasekhara, Research Professor
Department of Mechanical and Astronautical Engineering
Sponsor: Defense Intelligence Agency

OBJECTIVE: To establish a capability at the Naval Postgraduate School/Mechanical and Astronautical Engineering for analyzing the aerodynamic performance of missiles. Towards this goal, the performance of an SA-2 type missile or its derivative will be studied.

SUMMARY: Funding became available in April 2008. MSIC is particularly interested in analyzing incoming missiles such as the SA-2 and its derivatives. Hence, they supplied this geometry and some data for the research. Towards this end, U.S. Army AMRDEC and USAF AFRL were contacted with requests for their software tools. AMRDEC provided MissileLAB software that enables rapid generation of various missile geometries. The AFRL provided the Missile DATCOM package that actually performs the computations. A Singaporean student worked on the project for his Master’s thesis. Steady interactions continued with MSIC during the year. The effort focused on being able to match the experimental and simulated aerodynamic data that were provided by MSIC. Computations were carried out for a range of altitudes, from sea level to 100,000 feet. The missile angle of attack was varied up to 24 degrees and the...
Mach number from 0.8 up to 4.5 in discrete steps. By varying the surface roughness characteristics of the missile, it was possible to obtain a very close agreement for the skin friction data supplied by MSIC, however, the axial force did not agree well. These and other performance parameters are being analyzed in greater detail to achieve a better match.

PRESENTATION:


THESIS DIRECTED:


UNSTEADY AERODYNAMICS RESEARCH FOR MANEUVERING AN UNMANNED, COMBAT AIR VEHICLE (UCAV)
Muguru S. Chandrasekhara, Research Professor
Department of Mechanical and Astronautical Engineering
Sponsor: National University of Singapore

OBJECTIVE: To study and identify the unsteady aerodynamic characteristics of an unmanned, combat aircraft while performing prescribed maneuvers in the Naval Postgraduate School (NPS) water tunnel.

SUMMARY: A new three-year research proposal designed to study the unsteady, maneuvering aerodynamics of an unmanned, combat air vehicle (UCAV) was funded by the Singapore TDSI/TEMASEK group. The study was initiated in the Mechanical and Astronautical Engineering 15in x 20in water tunnel in May 2008. A Singaporean graduate student participated in the research for his Master’s thesis by conducting experiments on a UCAV 1303 model. This specific geometry was chosen since both the U.S. Air Force (AFRL) and the U.S. Navy (NAVAIR) are studying it in their TTCP program, and any new results can complement this program. The AFRL supplied the model geometry, which was adapted to satisfy the requirements of the NPS water tunnel, and two copies were fabricated. One was embedded with dye tubes for flow visualization studies. The other will be used with sting-mounted, strain-gage, load-measurement instrumentation. Custom phase-locking instrumentation was designed and built for synchronizing the multiple cameras that were used for capturing flow images. As is normal, the first phase of the study focused on identifying the major flow characteristics through flow visualization. Preliminary analysis of the images showed that the absence of a vertical tail in this model introduces unexpected vertical-flow behavior that is still being analyzed.

PRESENTATION:


THESIS DIRECTED:

OBJECTIVE: To address the development and implementation onboard an SUAV of the real-time algorithms of cooperative path-following and airspace de-confliction for multiple SUAVs operations.

SUMMARY: As the restricted airspace used in experiments gets more crowded, issues of airspace management and de-confliction become of paramount importance. As a result, the Naval Postgraduate School and AFSOC developed new algorithms that address these issues at both the local level (several UAVs cooperating to execute a mission) and at the air boss’ level.

At the local level, a team of UAVs is assigned a box that it cannot leave. Each UAV then cooperatively generates real-time trajectories that guarantee de-confliction for each UAV, as well as confine the UAV team to the assigned box. Trajectory generation is done in real-time using direct methods of optimal control that explicitly account for the communication structure of the underlying wireless network.

The status of each UAV team is displayed to the air boss by situational awareness software that monitors the airspace under his control, detects potential conflicts, and suggests potential conflict resolutions. The air boss may accept these suggestions or decide to execute an entirely different procedure. The paper includes a description of the algorithms involved and of flight test results.

PUBLICATION:


CONFERENCE PUBLICATIONS:


OBJECTIVE: To develop and flight test a “Control Over the Network” (CON) capability for small UAVs. The system is designed to provide simple and effective tools to navigate (high-level control function) a reconnaissance UAV from a remote platform by means of wireless network connection to the onboard avionics.

SUMMARY: The project objective is to define and demonstrate a concept by which task-force-level commanders and below can obtain a persistent, over-the-horizon surveillance capability for the purpose of target development and other missions without tasking national or theater-level assets. The goal is to increase the ISR capacity of units who normally would not rate the priority to task a Predator, Global Hawk, or U-2. There are two guiding tenets in developing this concept. First, the equipment and its control should be organic to the SOF unit or task force. Second, utilizing this capability should not require the soldier to carry any additional equipment into the field.

Initial research led to the idea of using networked, unmanned, aerial systems (UAS) to generate an over-the-horizon surveillance capability for SOF. The concept was demonstrated by forming a network comprised of a forward ground team, an inexpensive, testbed UAS equipped with an off-the-shelf video camera, a manned aircraft, and a tactical operations center. Connectivity was attained through a WaveRelay mesh structure at 2.4 GHz without using amplification.

The onboard instrumentation provides the following principal capabilities: 1) airborne mesh network node with relay capability; 2) navigation of the UAV to a location specified via the network; 3) stabilization of the gimbaled camera while pointing the camera at the desired target location; 4) real-time video feed to the network; and 5) support of the local situational awareness (SA) capability, including a shared view of current position, messaging, flight log for later analysis, and network performance monitoring.

The combination of these components allows for two principal missions: a) reconnaissance or convoying missions around the fixed or moving targets, and b) using the UAV as an airborne, mobile, network node.

CONFERENCE PUBLICATIONS:


THE DEVELOPMENT OF A TARGET-TRACKING AND MOTION-ESTIMATING CAPABILITY FOR SMALL, UNMANNED AIR VEHICLES (UAVS)
Vladimir N. Dobrokhodov, Research Assistant Professor
Isaac I. Kaminer, Associate Professor
Kevin D. Jones, Research Associate Professor
Department of Mechanical and Astronautical Engineering
Sponsor: Center for Defense Technology and Education for the Military Services

OBJECTIVE: To develop a vision-based target tracking and position-speed estimating capability for small, unmanned air vehicles (UAV); onboard implementation should allow both to autonomously track fixed and moving targets and to estimate target motion in the presence of occlusions and out-of-frame events typical for vision-based applications.

SUMMARY: This project addressed a vision-based, fast-motion, estimating algorithm of a target moving with time-varying velocity for a small, unmanned air vehicle (SUAV) equipped with a stabilized gimbal camera. This work is an extension of a previous project on vision-based target tracking and motion estimation where the SUAV equipped with a gimbaled camera achieved autonomous tracking of a target moving with constant speed while simultaneously estimating its motion. In this work, a previous assumption on fixed-target speed was relaxed to a time-varying case. This led to several new results in coordinated camera control and SUAV guidance, as well as in fast estimation of the target’s time-varying velocity. The estimation of the target’s velocity was formulated in order to apply a recently developed L1 rapid estimator. The estimator used two types of real-time measurements, including the target position in the center of the camera frame (provided by an image processing algorithm) and the relative altitude above the target (from an external geo-referenced database).

PUBLICATION:

CONFERENCE PUBLICATIONS:


THESIS ADVISED:
FLIGHT VALIDATION OF METRICS-DRIVEN ADAPTIVE CONTROL
Vladimir N. Dobrokhodov, Research Assistant Professor
Isaac I. Kaminer, Associate Professor
Kevin D. Jones, Research Associate Professor
Ioannis Kitsios, Postdoctoral Researcher
Department of Mechanical and Astronautical Engineering
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: To develop a complete framework for the design and experimental validation of metrics-driven adaptive control algorithms using unmanned platforms available at the Naval Postgraduate School (NPS) and the National Aeronautics and Space Administration (NASA). In particular, this research proposes to: identify suitable control-driven metrics to evaluate the performance of adaptive control algorithms in the presence of failures; use these metrics to develop verifiable, robust, adaptive-control architectures for validating the stability, performance, and robustness of these algorithms in the presence of failures, modeling uncertainties, and unknown disturbances to provide safe landing; extend existing software and hardware-in-the-loop (HITL) simulation capabilities at NPS to support the development and validation of the proposed adaptive-control algorithms; and conduct an extensive flight testing program at NPS and NASA to validate the performance of these adaptive control algorithms in the presence of failures.

It is noted that the robustness/stability margins of the proposed architectures resemble those for linear systems with an appropriate extension of the notion of phase margin to time-delay margin.

SUMMARY: Up-to-date efforts result in an integrated methodology for the development and flight validation of the metric-driven fast and robust adaptation algorithms that guarantee safe landing in the presence of control and engine failures. It demonstrates in flight that the unique capabilities inherent in this methodology can vastly improve the safety record of transport aviation as envisioned by NASA. This claim is supported by the underlying design paradigm of the proposed adaptive-control methodology and by its distinct difference from the existing approaches. Specifically, it allows for fast adaptation, which proves to be instrumental for improving both performance and robustness throughout the entire envelope, including emergency landing. Analytical computation of the gain and time-delay margins similar to linear systems and the ability for a priori prediction of the uniform performance bounds is what makes the Theory of Fast and Robust Adaptation an appropriate framework for addressing the milestones of the NASA IRAC program.

Integrating the L1 adaptive output feedback augmentation controller onboard a small UAV brings unprecedented benefits in situations where the UAV is in adverse flight conditions or is subject to the control surfaces failures. Since the nominal autopilot is not aware of a failure of one or several control surfaces, the integration of L1 adaptation allows for the fault detection and isolation task to be solved automatically without the need for reconfiguration of the existing inner-loop control structure of the nominal AP. As a result, the L1 augmented controller readjusts the control input that stabilizes the impaired airplane and uses the remaining control authority to steer the airplane along the re-defined path. Therefore, integrating L1 adaptation onboard increases the fault tolerance of the system.

Initial development of the control quality metrics resulted in establishing a set of qualitative measures that were verified experimentally in HIL and flight testing. It was experimentally shown in extensive HIL and flight testing that the L1-augmented system exhibits uniform degradation of tracking performance in the presence of increasing severity of the CS failure. Theoretical and experimental study of the remaining control authority and robustness is in progress.

Several major milestones were achieved on the experimental side of the project, including the development of a new HIL simulating capability for a Piccolo Plus AP that allows for advanced modeling of non-conventional airplane configurations and aerodynamics using the convenience of the Simulink development environment and control design toolboxes. Furthermore, a new modification of the RFTP was developed, providing a rigorous capability for flight testing airplanes with complex failures of control surfaces in various flight regimes and configurations.
CONFERENCE PUBLICATIONS:


AN EXPERIMENTAL INVESTIGATION OF FLAPPING-WING PROPULSION FOR HIGH-SPEED VESSELS

Kevin D. Jones, Research Associate Professor
Department of Mechanical and Astronautical Engineering
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To design, build, and evaluate a sub-scale model of an HSV-class catamaran ship using flapping-wings for propulsion in place of the usual water jets. A previous study indicated superior propulsive efficiency for a pair of flapping wings operating in a bi-plane arrangement. However, the numerical study did not include several aspects of the problem that may be influential to performance and control, and these will be evaluated experimentally in this study. Areas of particular interest include mechanical losses, use of the flapping wings for pitch-trim, reverse thrust, and effectiveness in heavy sea states.

SUMMARY: A simplified multi-hull configuration was designed and fabricated. The model was sized based on availability of commercial, off-the-shelf hardware from the hobby industry. The model beam was set to about one meter, with a length consistent with current HSV hulls. The electric-powered radio-controlled model will be evaluated for static thrust in a large water tank in the new Unmanned Systems Lab and at speed in local waterways and possibly on the bay to evaluate functionality in the presence of rough water.

KEYWORDS: Flapping-Wing Propulsion, High Speed Vessel

AN EXPERIMENTAL INVESTIGATION OF FLAPPING-WING PROPULSION FOR HIGH-SPEED VESSELS

Kevin D. Jones, Research Associate Professor
Department of Mechanical and Astronautical Engineering
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To instrument and evaluate a sub-scale model of an HSV-class catamaran ship using flapping-wings for propulsion in place of the usual water jets. A previous study indicated superior propulsive efficiency for a pair of flapping wings operating in a bi-plane arrangement. However, the numerical study did not include several aspects of the problem that may be influential to performance and control, and these will be evaluated experimentally in this study. Areas of particular interest include mechanical losses, use of the flapping wings for pitch-trim, reverse thrust, and effectiveness in heavy sea states. Another previous study led to the design and fabrication of a sub-scale test model.

SUMMARY: The sub-scale multi-hull configuration designed and fabricated in the previous study was instrumented and evaluated in this investigation. The electric-powered radio-controlled model was
evaluated for static thrust in a large water tank and at speed in local waterways to evaluate functionality in the presence of rough water.

**KEYWORDS:** Flapping-Wing Propulsion, High Speed Vessel

### MODELING AND ANALYSIS OF COMPOSITE SCARF JOINTS

Young W. Kwon, Professor  
Department of Mechanical and Astronautical Engineering  
Sponsor: Naval Surface Warfare Center-Carderock Division

**OBJECTIVE:** To develop a modeling technique to evaluate and predict the scarf joint strength of textile composites.

**SUMMARY:** The scarf joint has been considered for fabrication and repair of composite structures in the Navy. For example, the superstructure in a ship has been built out of composite materials with the scarf joint technique. This requires reliable analysis techniques to evaluate the interface strength of the scarf joint. As a result, the present study developed a consistent modeling technique to predict the failure strength of the interface joint using a multiscale approach. The developed techniques were assessed by comparison with experimental data; the comparison was very favorable for both glass and carbon composites under tensile or compressive loading.

**PUBLICATION:**


**CONFERENCE PUBLICATION:**


**PRESENTATION:**


**THESIS DIRECTED:**

One student is working on the project.

**KEYWORDS:** Composites, Modeling and Simulation, Scarf Joint, Interface Strength

### MODELING AND TESTING OF COMPOSITE STRUCTURE UNDER IMPACT LOADS

Young W. Kwon, Professor  
Department of Mechanical and Astronautical Engineering  
Sponsor: Office of Naval Research

**OBJECTIVE:** To understand the dynamic response of composite structures subjected to impact loading when the structures were in air or under water.

Because the impedance of water is significantly higher than that of air, the dynamical response of an underwater structure is strongly affected by the surrounding water medium through its fluid-structure interaction, even without considering the environmental effects, such as moisture absorption and the
resultant material property changes. As a result, dynamical behavior and failure modes/mechanisms of composite structures can be quite different for underwater applications. This research will investigate the fluid-structure interaction effect on composite structures that are subjected to dynamic impact and impulse loading. Both experimental and numerical works are proposed to complement and strengthen the research. The study will investigate the dynamical responses of composite structures immersed in water which is subjected to impact or impulse loading. Furthermore, dynamical responses of the structures in water and air will be compared to enhance the understanding of the effects of fluid-structure interaction on marine-composite structural behaviors through both experimental and numerical studies. In addition, a parametric study will be undertaken in order to identify the major factors that influence composite structures in terms of fluid-structure interaction effects.

**PUBLICATION:**


**PRESENTATION:**


**THESIS DIRECTED:**

One student is working on the project.

**KEYWORDS:** Composites, Fluid-Structure Interaction, Modeling and Simulation, Impact Loading

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**MODELING OF A RAILGUN**

*Young W. Kwon, Professor*

*Department of Mechanical and Astronautical Engineering*

*Sponsor: Unfunded*

**OBJECTIVE:** To develop a computer model to predict railgun performance.

**SUMMARY:** Finite-element-based multiphysics modeling was conducted for a railgun launcher to predict the exit velocity of the launch object and temperature distribution. For this modeling, electromagnetic field analysis, heat transfer analysis, thermal stress analysis, and dynamic analysis were conducted for a system consisting of two parallel rails and a moving armature. In particular, emphasis was given to modeling the contact interface between the rails and the armature. A contact theory was used to estimate the electric and thermal conductivities at the interface. Using the developed model, a parametric study was conducted to understand the effects of various parameters on the exit velocity and the temperature distribution in the railgun launcher.

**PUBLICATION:**


**KEYWORDS:** Rail-Gun, Finite Element Method, Electromagnetic Field, Contact Interface, Thermal Stress
MULTISCALE AND MULTIPHYSICS MODELING
Young W. Kwon, Professor
Department of Mechanical and Astronautical Engineering
Sponsor: Unfunded

OBJECTIVE: To model computational techniques for multiscale and multiphysics modeling of various engineering problems.

SUMMARY: In order to better understand the physics behind various scientific phenomena and enhance the prediction of those phenomena, multiscale and multiphysics modeling and simulation techniques are very beneficial. The scale varies from nano- to macro-size, i.e., from atoms and molecules to engineering bulk materials. In addition, multiphysics includes solid, fluid, and thermal behaviors, etc. To achieve this goal, various computational techniques were coupled in order to take advantage of individual techniques. For example, the molecular dynamics, finite element method, finite difference method, element free method, lattice Boltzmann method, cellular automata, etc., have been coupled to solve multiscale and multiphysics problems.

PUBLICATIONS:


KEYWORDS: Multiscale, Multiphysics Model

A STUDY OF THE EFFECT OF CARBON NANOTUBES ON COMPOSITE INTERFACE JOINTS
Young W. Kwon, Professor
Department of Mechanical and Astronautical Engineering
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To investigate the effect of carbon nanotubes on the interface strength of composite joints.

SUMMARY: Carbon nanotubes were introduced at the interface of composite joints. Composite specimens were prepared at the labs with and without carbon nanotubes at their interfaces using the vacuum-assisted, resin-transfer molding technique. The study found that carbon nanotubes were not displaced throughout the resin-transfer molding process. In order to determine the fracture toughness of the composite interface with or without carbon nanotubes, composite beams with a pre-existing crack were fabricated. The samples were tested for Mode I, Mode II, and a mixed mode. The test results showed a significant improvement of fracture toughness due to carbon nanotubes, especially for Mode II. In addition, the study provided an understanding of the role of carbon nanotubes in enhancing fracture toughness.
PUBLICATIONS:


CONFERENCE PUBLICATION:


PRESENTATION:


THESIS DIRECTED:


KEYWORDS: Composites, Carbon Nanotubes, Scarf Joint, Interface Strength

A STUDY OF THE FRACTURE TOUGHNESS OF COMPOSITE/METAL HYBRID INTERFACE STRENGTH

Young W. Kwon, Professor

Department of Mechanical and Astronautical Engineering

Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To measure the fracture toughness of composite/metal hybrid interface joints.

SUMMARY: In order to join a composite structure to a metallic structure, metal-wire mats were co-cured with composite laminas using the vacuum-assisted, resin-transfer molding (VARTM) technique. Then, interface fracture toughness was measured for a Mode II fracture for various lay-up and interface conditions. The study included interfaces of metal-wire to composite, composite to composite, and metal-wire to metal-wire. In addition, the lay-up orientations of metal-wire mats were varied between 0 and 90 degrees. The study also examined the crack propagation from a composite to a metal/composite interface. During the test, the digital image correlation technique was applied to capture the strain field around the crack tip. The results suggested that a hybrid metal-wire/composite laminate would be effective for connecting a composite structure to a metallic structure as long as some critical interface conditions were avoided.

PUBLICATION:

PRESENTATION:


KEYWORDS: Composite/Composite Interface, Composite/Metal Interface, Carbon Nanotubes, Interface Fracture Toughness, Digital Image Correlation Technique

AN ADVANCED CONTROL ALGORITHM STUDY

I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: Secretary of the Air Force/FMBMB-AFOY

SUMMARY: A pseudospectral framework for the integrated control and optimization of several systems was developed and analyzed. Because the proposed approach was only exploratory in nature, it was shown that the development of a real-time optimal controller would indeed have a long-term, sustained impact on the development of advanced systems.

ADVANCED OPTIMAL CONTROL STUDIES

I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: Defense Advanced Research Projects Agency

SUMMARY: Certain key problems arising in a cross-section of disciplines were analyzed. Upon analysis, a few select problems were proposed to the sponsor as a means to advance the application using recent results from optimal control theory.

ADVANCED OPTIMAL-GUIDANCE ALGORITHM DEVELOPMENT

I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: The Boeing Company

SUMMARY: The superiority of pseudospectral optimal-control techniques over standard Runge-Kutta methods was demonstrated. This was done by comparisons of numerical trajectory modeling/optimization algorithms applied to the guidance of aerospace vehicles. Modeling details were shared with Boeing to enable extension to other applications.

ADVERSARIAL SPACECRAFT SYSTEMS IDENTIFICATION

I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: Secretary of the Air Force/FMBMB-AFOY

SUMMARY: An unscented Kalman filter for system identification without using in situ measurements was developed. Measurements were obtained using motion-capture cameras. These measurements were then used for system identification.
**MECHANICAL AND ASTRONAUTICAL ENGINEERING**

**BOHR-FROZEN FORMATION FOR MULTI-SATELLITE SYSTEMS**  
I. Michael Ross, Professor  
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group  
Sponsor: Air Force Research Laboratory

**SUMMARY:** Systematically explored relative orbits by integrating concepts from periodic optimal-control theory, pseudospectral methods, and Bohr’s concept of almost periodic functions. The research led to the discovery of new J2-invariant relative orbits and new relative orbits for large separation distances, particularly for non-circular reference orbits.

**CMG EXPERIMENTS**  
I. Michael Ross, Professor  
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group  
Sponsor: Secretary of the Air Force/FMBMB-AFOY

**SUMMARY:** This is an ongoing project to implement and experiment with a real-time optimal-control algorithm. A CMG testbed is currently under procurement. Simulations show that the algorithm outperforms existing CMG controllers. The implementation and experimentation of this algorithm will be done in several stages with different options.

**THE DEVELOPMENT OF A RAPID MISSION DESIGN TOOL FOR THE CEV**  
I. Michael Ross, Professor  
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group  
Sponsor: NASA Johnson Space Center

**SUMMARY:** This is an ongoing research project aimed at developing CEV trajectories from low lunar orbit to the Earth interface. Researchers continue to collaborate with Johnson Space Center engineers towards the goal of developing a rapid mission design tool for the CEV. Preliminary results show that fuel savings are possible when compared to the benchmark trajectory provided by NASA. These results are now being verified through the application of various tools from optimal control theory.

**IN SITU SPACECRAFT SYSTEM IDENTIFICATION USING FAKE MEASUREMENTS**  
I. Michael Ross, Professor  
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group  
Sponsor: Secretary of the Air Force/FMBMB-AFOY

**SUMMARY:** The norm of a quaternion is unity. Enforcing this constraint for state estimation has long been performed through various ad hoc concepts that are not entirely satisfactory from a theoretical point of view. This research showed that a fake measurement can be introduced into the estimation process and the quaternion unity norm can be guaranteed at convergence.

**MINIMUM-FUEL RELATIVE-MOTION TRAJECTORIES NEAR AN UNCOOPERATIVE TARGET**  
I. Michael Ross, Professor  
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group  
Sponsor: Secretary of the Air Force/FMBMB-AFOY

**SUMMARY:** A methodology for deriving minimum fuel trajectories for the relative motion of a spacecraft about an uncooperative target was developed. The methodology was based on combining concepts from optimal control theory and orbital mechanics. Additional research questions were identified and a new problem was conceptualized.
OPTIMAL CONTROL EXPLORATIONS
I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: Secretary of the Air Force/FMBMB-AFOY

SUMMARY: This is an ongoing project directed at exploring advances in optimal control for various applications, ranging from space systems to robotic systems. A breakthrough in robotics was achieved under this program: first, the concept of a Hausdorff metric space was used to define distances; then, rather than compute this computationally intensive distance function, concepts from optimization theory were used to introduce a sub-problem; then, this sub-problem was imbedded in the control problem via the introduction of artificial control variables to develop collision-free minimum-time state trajectories.

A PSEUDOSPECTRAL APPROACH FOR CONTROL AND OPTIMIZATION OF LARGE, SEGMENTED MIRRORS
I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: Secretary of the Air Force/FMBMB-AFOY

SUMMARY: Researchers analyzed the problem of integrated control and optimization of very large-scale control systems (thousands of sensors and actuators) found in the design of large telescopes based on segmented-mirror technology. A major problem was found in the computational elements involved in the reconstruction of the wave-front using Shack-Harmann sensors. Researchers are now conducting follow-on research to determine how to reduce this computational burden.

PSEUDOSPECTRAL METHODS FOR OPTIMAL CONTROL AND ESTIMATION WITH APPLICATIONS TO SPACE
I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: Air Force Office of Scientific Research

SUMMARY: A unified, theoretical foundation for pseudospectral methods for optimal control was developed. Theoretical foundations for the estimation of general nonlinear systems were also developed using pseudospectral methods. The concept of the Caratheodory-pi solution was introduced to achieve real-time optimal control of space systems.

THE TALON DARK MIRROR
I. Michael Ross, Professor
Department of Mechanical and Astronautical Engineering and Space Systems Academic Group
Sponsor: Air Force TENCAP

SUMMARY: A feed-forward optimal-control approach for the practical implementation of a pre-real-time, optimal-control algorithm was analyzed. This work is still ongoing and plans are now underway to determine whether the existing results could be mapped to a flight experiment onboard an Air Force spacecraft.
PUBLICATIONS


CONFERENCE PUBLICATIONS


PRESENTATIONS


Kwon, Y.W., “Multiscale Modeling of Materials and Structures,” Aalborg University, Denmark, April 2008 (invited).


CONTRIBUTIONS TO BOOKS


DEPARTMENT OF
METEOROLOGY

PHILLIP A. DURKEE
CHAIR
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 60 years ago, the Naval Postgraduate School (NPS) was responsible for establishing a flourishing 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 the Fleet Numerical Meteorology and Oceanography Center-FNMOC). The Navy chose to move FNMOC to Monterey to take advantage of the presence of NPS and 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 include 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.

In recent years, the Department of Meteorology has served a broad spectrum of research interests supported by ONR, NSF, NASA, NOAA, NGA, and other DoD and civilian national research sponsors.

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, Professor Wendell Nuss, Professor Patrick Harr, Professor Michael Montgomery, Assistant Professor Karl Pfeiffer (Military Faculty), Research Associate Michael Bell, and Research Assistant Professor Richard Moore
- **Numerical Weather Prediction (NWP):**
  Research Associate Hway-Jen Chen, Assistant Professor Tony Eckel (Military Faculty), and Assistant Professor Rebecca Stone (Military Faculty)
- **Environmental Analysis and Visualization:**
  Research Associate Mary Jordan
• **Air-Sea Interactions:**
  Professor Kenneth Davidson, Research Associate Paul Frederickson, and Assistant Professor Rebecca Stone (Military Faculty)

• **Satellite and Ground-Based Remote Sensing:**
  Professor Philip Durkee, Research Associate Kurt Nielsen, and Research Associate Michael Bell

• **Tropical Meteorology:**
  Distinguished Professor Russell Elsberry, Distinguished Professor Chih-Pei Chang, Professor Patrick Harr, Professor Michael Montgomery, Research Associate Hway-Chen, Research Associate Michael Bell, Research Assistant Professor Zhuo Wang, and Research Associate Stephanie Zick

• **Tropical Cyclone Motion:**
  Professor Patrick Harr, Professor Michael Montgomery, Research Associate Michael Bell, Research Assistant Professor Zhuo Wang, and Research Associate Stephanie Zick

• **Boundary Layer Meteorology:**
  Professor Kenneth Davidson and Professor Qing Wang

• **Climate Dynamics:**
  Distinguished Professor Chih-Pei Chang, Research Associate Hway-Jen Chen, Senior Lecturer Tom Murphree, and Research Assistant Professor Zhuo Wang

• **Atmospheric Factors in EM/EO Propagation:**
  Professor Kenneth Davidson, Research Associate Professor Peter S. Guest, and Research Associate Paul Frederickson

• **Polar Meteorology:**
  Research Associate Professor Peter S. Guest

**RESEARCH FACILITIES:**

• **IDEA Laboratory:** The Interactive Digital Environmental Analysis 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.

• **BEC Laboratory:** The Battlespace Environment Characterization Laboratory is designed to support complex data acquisition, analysis, and decision-making capabilities for a variety of environmental problems and DoD applications.

• **RSL:** The Remote Sensing Laboratory operates a SeaSpace NOAA satellite receiver that collects and processes environmental data in support of atmosphere and ocean analysis.

• **SAFL:** The Synoptic Analysis and Forecasting Laboratory 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.

• **ABLML:** The Atmospheric Boundary Layer Measurements Laboratory 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)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include 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: $3.5M
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DEPARTMENT OF
METEOROLOGY

2008
Faculty Publications
and Presentations
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 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 models and synoptic observation capabilities. They are achieved through the employment of modern dynamical and mathematical principles, numerical and statistical methods, computational and graphical facilities, and in-site and remote sensing observations.

CURRICULA SERVED:

- Meteorology and Oceanography
- Operational Oceanography
- Oceanography
- Undersea Warfare

DEGREES GRANTED:

- Master of Science in Meteorology and Physical Oceanography
- Master of Science in Physical Oceanography
- Doctor of Philosophy in Physical Oceanography

RESEARCH THRUSTS:

- Acoustical Oceanography
- Air-Sea Interaction and Ocean Turbulence
- Coastal/Littoral/Nearshore Oceanography
- Numerical Prediction and Data Assimilation
- Gl&S and Navigation
- Polar Oceanography

RESEARCH FACILITIES:

- Research Vessel Point Sur
- Point Sur Listening Station
- Rapid Environmental Assessment Laboratory
- Ocean Acoustic Observatory at Point Sur
- Computer Graphics Laboratory
- Monterey Inner Shelf Observatory
- Moored Equipment Laboratory
- Calibration Laboratory
- Tactical Environmental Support Laboratory
• Interactive Digital Environmental Analysis

RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Oceanography is provided below:

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<td>Traganza, Eugene Dewees</td>
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AN ANALYSIS OF THE SOUTH CHINA SEA SHELF AND BASIN ACOUSTIC TRANSMISSION DATA
Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To complete the analysis of both the shelf and basin acoustic transmission data collected from the Northeastern South China Sea (NE SCS) during the Windy Island Soliton Experiment (WISE). These data were collected between April 2005 and October 2006.

The objectives of the NE SCS shelf acoustic data analysis are twofold: the first is to compare and contrast, in terms of phenomenology and statistics, the sound intensity fluctuations resulting from a transmitted acoustic pulse through nonlinear depression-internal waves, nonlinear elevation-internal waves, and/or a mix of both types of waves. The second is to develop and validate a modified theory that expands upon previously established theories of the statistics of sound intensity fluctuations (Dyer (1970) and Makris (1996)) by incorporating critical signal parameters and channel characteristics, including signal and channel bandwidths, multipath arrival times (separations), and additional bottom-induced variance, all of which control the number of independent intensities/arrivals in the received signal.

The primary objective of the basin acoustic data analysis is to study and characterize the supertidal-to-seasonal-scale impacts of the transbasin, nonlinear internal waves on long-range transmission loss. A secondary objective is to understand the variability of the observed ambient-noise level in the basin and quantify what portion, if any, of this variability is related to the nonlinear, internal-wave activities/climatology.

SUMMARY: In the shelf experiment, a moored 400-Hz sound source, a moored vertical-line hydrophone array, moored temperature strings, and a towed Scanfish CTD were employed to obtain simultaneous measurements of the fluctuating acoustic-signal intensity and of the variable sound speeds for a period of three days in April 2005. The analysis of this dataset was completed in FY08, with experimental, modeling, and theoretical results documented in Reeves’ Ph.D. thesis. Two manuscripts are currently in preparation for submission to refereed journals.

The basin experiment began in April 2005 and ended in October 2006. It entailed seasonal cruises to maintain a moored source and a moored receiver monitoring the periodic transmissions of a 400-Hz signal across the basin. In FY08, processing and analysis of the data from the last deployment spanning the period from June to October 2006 were completed. The results were presented at the 155th Meeting of the Acoustical Society of America.

PRESENTATIONS:


THESIS DIRECTED:


KEYWORDS: Littoral Acoustics, Shelfbreak, Nonlinear Internal Waves
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
John E. Joseph, Research Associate
Department of Oceanography
Sponsor: Chief of Naval Operations (N45)

SUMMARY: Distribution restricted to Department of Defense (DoD) and DoD contractors.

PUBLICATION:

CONFERENCE PRESENTATION:

THESES DIRECTED:


TECHNICAL REPORTS:


KEYWORDS: Odontocetes, Underwater Acoustics, Sonobuoys, Hydrophones

BASIC RESEARCH ON OCEAN ANALYSIS, MODELING, AND PREDICTION
Peter C. Chu, Professor
Department of Oceanography
Sponsor:

SUMMARY: Development of a new theory for ocean model predictability. The model predictability is usually measured by instantaneous error (IE). The predictability is regarded as the model error growth due to the initial condition error. This implies that the initial condition error should be given. When the initial error is uncertain, the IE measure cannot be used in evaluating the model predictability. A theoretical framework was developed for predictability evaluation using the PT measure for uncertain initial error.

Development of a coastal atmosphere-ocean coupled system (CAOCS). 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 (MM5), with 40 km horizontal resolution and 16 vertical levels.

Development of a nowcast/forecast system for the East Asian Marginal Seas. Part of the work was the major oceanographic part of the international South China Sea Monsoon Experiment (SCSMEX).

Development of a new theory for flow reconstruction. A new theory for reconstructing noisy and sparse velocity data analysis was developed.

A LEADERSHIP ROLE IN THE OFFICE OF NAVAL RESEARCH MINE BURIAL PREDICTION PROGRAM
Peter C. Chu, Professor
Department of Oceanography
Sponsor:

SUMMARY: As a leader of the impact-burial prediction team, Peter Chu actively participated in program planning and experiment design. He obtained an Office of Naval Research grant to conduct research and attracted Naval Postgraduate School students to do their theses in this program for their Master’s degrees. A new, 3D Mine Impact Burial Prediction Model (IMPACT35) has been developed for the mine warfare community.

LITTORAL OCEANOGRAPHY FOR MINE WARFARE
Peter C. Chu, Professor
Department of Oceanography
Sponsor:

SUMMARY: Peter Chu has played a leadership role in the Littoral Oceanography for Mine Warfare Project through interdisciplinary research and course development. Sponsored by the Naval Oceanographic Office (NAVO), Peter Chu established a multi-institutional research program entitled “Environmental Effect on Naval Warfare Simulations” with the Naval Oceanographic Office, Naval Coastal System Station. Researchers installed and tested the Mine Impact Burial Model from NAVO into the Naval Postgraduate School Secure Computing and Simulation Laboratory. Various environmental effects on the mine impact burial have been obtained.
OBJECTIVE: To derive methods for the practical analysis of Lagrangian float observations from boundary current regions using advanced mathematical methods. This is a collaborative project with Dr. Leonid Piterbarg of the Mathematics Department of the University of Southern California.

SUMMARY: The diffusion limit of the random displacement model was used to quantify westward transport at intermediate depths in the California Current. Exit-time statistics for RAFOS float observations were used. According to the model, inhomogeneous eddy diffusion with intermittent, short-duration, advective motion represented the alongshore averaged WT. The zonal coefficient of the diffusion grew as a power law with distance from the coastline (the power exponent was close to one), a signature of a nonlinear, quasi-geostrophic, turbulent regime in the California Current system. Typical values of float drift velocity were about 1.8-2 cm/s, but the velocity reached as high as 4-6 cm/s offshore during the upwelling season. A transition zone between nearshore and offshore was clearly identified only in spring and was either very narrow or absent in other seasons.

The UCLA ROMS, with a horizontal grid spacing of 3.5 km for the region off central California, was compared to RAFOS float observations and satellite altimetry on meso/submesoscales. The approach used two new metrics for model-data comparison and suggested how to calculate these metrics for different spatio-temporal scales. The first metric consisted of the first two moments of exit-time and was used to compare ROMS against RAFOS float observations at mid-depths (between 300 m and 350 m). Exit-time is the length of time a float launched at a point takes to leave a domain for the first time. The second metric was spectral entropy; it was used to estimate how well ROMS reproduced variability of the sea surface height (SSH) anomaly field extracted from an AVISO dataset (1992-2007) for specified temporal and spatial scales. Calculations showed that ROMS reproduced the mid-depth mesoscale/submesoscale currents next to the coast in a very accurate manner (statistics of observed float trajectories were reproduced by ROMS with an accuracy better than 95%); but ROMS overestimated the speed of westward drift of floats by as much as 20%-30% at distances greater than 350 km from the coastline. ROMS predicted the variability of the mesoscale (100-400 km) SSH anomaly field for temporal scales of 1-6 months with reasonable accuracy. A wavelet-transform modulus-maxima technique applied to the spectral entropy of the SSH anomaly also demonstrated good agreement between ROMS and satellite altimetry for mesoscales characterized by Hölder exponents for 1-6 month time scales.

PUBLICATIONS:


CONFERENCE PRESENTATIONS:


KEYWORDS: California Current, Lagrangian Measurements, Isentropic Analysis, Mesoscale Eddies

OCEANOGRAPHIC CONDITIONS OFF CENTRAL CALIFORNIA

Curtis A. Collins, Professor
Department of Oceanography

Sponsor: National Marine Fisheries Service, National Oceanic and Atmospheric Administration

OBJECTIVE: To monitor the state of the California Current off central California using quarterly research cruises.

SUMMARY: Monitoring cruises were carried out on R/V Point Sur in June 2008 and October 2008. Gale-force winds prevailed during the June cruise and only about three-quarters of the stations to the southwest of Monterey were occupied. Those stations indicated cold, upwelled waters next to the coast, which overlaid a strengthened undercurrent. California Current waters were observed about 150 kms from the coast and flowed to the south-southeast.

In October, monitoring lines off Monterey and San Francisco were occupied. Satellite imagery showed that the inshore edge of the California was deflected to 126°W near Pt. Arena and remained near this meridian along the central coast. Poleward flow was observed over the shelf and next to the coast. Off Monterey, poleward flow was also observed in the middle of the section, but it was re-circulating subarctic waters to the north. At the offshore edge of the section, the inshore edge of the California Current was observed and southward flow was encountered.

In December 2008, NOAA advised that NOAA Ship David Starr Jordan would not be available to support winter observations off central California. Alternate arrangements were made to use R/V Western Flyer to collect data along the section to the southwest of Monterey.

Results of the 2007 monitoring cruises were published in CalCOFI Reports (see reference below). Monterey Bay temperature and salinity anomalies were inversely correlated and showed that spring and summer temperature (salinity) anomalies were -1°C (ΔS=0.04) cooler (saltier) than normal, most likely due to the strong and persistent upwelling favorable winds that occurred. Summer chlorophyll a concentrations remained about 3 mg/m^3 higher than normal for the fourth year in a row. This marks the eighth year since 1999 that positive anomalies occurred. Dinoflagellate concentrations returned to normal in Monterey Bay after three years of higher-than-normal abundance.

CalCOFI hydrographic stations along Line 67 (off Monterey) and 60 (off San Francisco) to station 90 were occupied in June and November 2007. Compared with the 1988-2001 climatology, conditions to the southwest of Monterey (Line 67) indicated that subarctic influences (versus equatorial) were stronger. For example, the inshore edge of the California Current (marked by S=32.9-33.0) intersected the section at about its halfway point, 150 km from Monterey Bay. During 1988-2003, the inshore edge of the California Current was found near the offshore limit of the section except during the period of the 1997-98 El Niño. Central California conditions reported in 2006 continued. The mean halocline temperatures remained low, 8.8°C, and the thermocline salinity (34.33) and deep salinity (34.1) continued to freshen. For upper waters (T>10°C), strong summer upwelling conditions resulted in a mean salinity of 33.3 in June, which by November had decreased to 33.0.
OCEANOGRAPHY

PUBLICATION:


CONFERENCE PRESENTATION:


CONTRIBUTION TO BOOK:


TECHNICAL REPORTS:


KEYWORDS: California Current System, Coastal Circulation, Central California

ANALYSIS AND MODELING OF OCEAN ACOUSTIC FLUCTUATIONS AND MOORED OBSERVATIONS OF THE PHILIPPINE SEA SOUND-SPEED STRUCTURE

John Colosi, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: In the interest of improving ocean acoustic modeling and prediction capability, this study seeks to establish the connections between oceanographic sound-speed variability and observed acoustic fluctuations from both deep- and shallow-water environments. The basic science of this proposal is well aligned with the interests of the Navy and the Department of Defense, as undersea acoustic surveillance and remote sensing rely critically on a clear knowledge of the oceanographic sound-propagation environment and on a firm understanding of the appropriate acoustic-propagation physics given a particular environment.

SUMMARY: This project started in October 2008, and the main efforts to date have been the preparation of instruments for the spring 2009 Philippine Sea pilot study.

PUBLICATIONS:

OCEANOGRAPHY


PRESENTATIONS:


THESES DIRECTED:


AN ANALYSIS OF OCEANOGRAPHIC AND ACOUSTIC FLUCTUATIONS FROM DEEP AND SHALLOW WATER ENVIRONMENTS: TOWARDS A UNIFICATION OF OBSERVATIONS, MODELS, AND THEORY

John Colosi, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: In the interest of improving ocean acoustic modeling and prediction capability, this study seeks to establish the connections between oceanographic sound-speed variability and observed acoustic fluctuations from both deep- and shallow-water environments. The basic science of this proposal is well aligned with the interests of the Navy and the Department of Defense, as undersea acoustic surveillance and remote sensing rely critically on a clear knowledge of the oceanographic sound-propagation environment and on a firm understanding of the appropriate acoustic-propagation physics given a particular environment.

SUMMARY: Work on this project has focused on developing acoustic models for the prediction of the effects of internal waves on acoustic propagation in both the deep and shallow water. In shallow water, a new analytic model has been developed to predict the coupling of acoustic modes by nonlinear, internal wave packets; in deep water, a Feynman path integral method has been developed to predict the distortion of acoustic pulses as they travel through the deep-water, random internal wave field. Working with a new student, Kim Freitas, the principal investigators (PI) have developed a 4D ocean mesoscale model that will be used in the Philippine Sea to examine the effects of eddies on acoustic transmission loss and towed/vertical array performance.

The PI has also been actively involved in the final planning stages for the 2009-2011 Philippine Sea experiment, where the Naval Postgraduate School will take the lead role in acquiring environmental information, as well as supplying an acoustic transceiver node. These activities resulted in a 60% increase in Office of Naval Research funds over the next three years.
THE EVOLUTION OF OCEAN SURFACE WAVES ACROSS A MUDDY CONTINENTAL SHELF

Thomas H.C. Herbers, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To understand the complex interactions between ocean surface waves and a muddy seafloor, and to incorporate the dominant wave-damping mechanisms into a continental-shelf-scale wave-prediction model. The specific objectives include: 1) obtain detailed field measurements of wave evolution across a muddy continental shelf, 2) test competing hypotheses for mud-induced wave attenuation, and 3) perform a high-resolution hindcast with the wave prediction model SWAN to assess the effects of a muddy environment on swell decay and fetch-limited wind wave growth.

SUMMARY: It is well known that the presence of mud deposits on the continental shelf can cause dramatic damping of ocean surface waves, but quantitative field observations are scarce. Researchers recently participated in a comprehensive field experiment on the wide and muddy shelf of western Louisiana to investigate the interaction of wind-generated ocean-surface waves with a muddy seafloor. An extensive array of instruments was deployed during February-March 2008, including two directional waverider buoys, six bottom tripods equipped with a pressure-velocity sensor and a current profiler, and six bottom tripods equipped with a pressure sensor. The two-dimensional array consisted of two cross-shore transects and an alongshore transect spanning a 40 by 25 km area in depths ranging from 13 to 4 m. The dataset included numerous local wind-sea events, with wave directions predominantly from the south (i.e., onshore propagation). Box cores were collected at all instrument sites to characterize the surficial sediment properties (in collaboration with Ana Garcia-Garcia of the University of California-Santa Cruz).

Preliminary analysis, conducted by LT Lincoln Trainor as part of his Master’s thesis, generally showed a consistent decay of waves from the deeper to the shallower instruments, similar to earlier observations. The wave spectra evolution showed strong decay (as much as an order of magnitude) of high-frequency, wind-sea spectral levels and weaker decay at the lower swell frequencies. These observations suggest that the dissipation is not the result of a direct wave-bottom interaction (which would affect only longer-wavelength waves), but possibly the result of heavy sediment suspension over the entire water column affecting the hydrodynamics of short-wavelength waves. The observed decay was strongest at a shallow site, where box cores showed fresh mud deposits and a visibly murky sea surface was observed during the experiment cruises.

PUBLICATIONS:


KEYWORDS: Ocean Surface Waves, Continental Shelf, Nearshore Processes
IN SITU WAVE OBSERVATIONS IN THE HIGH-RESOLUTION AIR-SEA INTERACTION DRI

Thomas H.C. Herbers, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Ocean wave prediction models, based on a spectral energy balance, are widely used to obtain wind-wave forecasts and hindcasts on global and regional scales. However, these inherently stochastic models assume a Gaussian and homogeneous sea state and thus do not describe the nonlinear instability processes that can dramatically alter the structure of wave groups and produce anomalously large waves, also known as “freak” or “rogue” waves. Fully deterministic modeling capabilities are now becoming available that incorporate these nonlinear effects and provide the detailed, phase-resolved, sea-surface predictions needed in many applications. Concurrent with the development of new models, advances in radar remote-sensing techniques are enabling the detailed observation of the sea surface on the scales of wave groups and individual waves. The long-term goal of this research is to test these emerging new models and measurement technologies in realistic sea states and use them to better understand and predict the wave group structure and occurrence of extreme waves in the ocean. Specific objectives include: 1) observe the nonlinear evolution of wave groups in realistic, broad-band sea states, 2) provide ground-truth data for testing the capabilities of ship-board wave radar systems, and 3) provide in situ wave data for the verification of phase-resolving wave-prediction models.

SUMMARY: During FY08, the principal investigators participated in the continued planning of the High-Resolution Air-Sea Interaction DRI. During several meetings at the Scripps Institution of Oceanography, a plan was developed for the main three-year phase of the DRI (FY08-FY10). The field experiments will be conducted in two stages: a pilot experiment in spring 2009, followed by the main experiment in spring 2010. Both experiments are tentatively planned to take place off the California coast in about 500 m depth.

The tentative plan for the pilot experiment involves deploying five free-drifting, Datawell, surface-following buoys. Other DRI participants will collect shipboard and airborne radar observations of the surface wave field, video observations of wave breaking events, and various atmospheric measurements. The main goals are to try out different buoy-deployment strategies to optimize their use in the main experiment and to test the precise synchronization in time and space with other experiment components to achieve a fully integrated dataset. The pilot experiment will also provide a dataset for preliminary analysis of nonlinear wave-group evolution physics that will be used to improve the design of the main experiment.

In the main experiment, centered around the Scripps platform FLIP in about 500 m depth, the plan is to deploy a more extensive array of surface buoys spanning an area of about 10-20 km that contains the footprints of FLIP-based and shipboard radar systems.

PUBLICATIONS:


KEYWORDS: Ocean Surface Waves, Sea State
layer processes, and enhanced, nonlinear wave-wave interactions. The long-term goal is to understand these physical processes and develop accurate wave-prediction models for regional and near-shore applications. Specific objectives include: 1) estimate bottom drag coefficients for a range of hydrodynamic (sub-critical to large Shields numbers) and morphodynamic (from relict and active sand ripples to sheet flow) conditions in different sediment environments (including fine and coarse sand); 2) evaluate the role of bottom friction in the spectral energy balance of depth-limited wind seas and improve the source term parameterization used in wave prediction models; 3) evaluate the effects of cubic nonlinearity on wave group evolution in energetic, natural sea states on the continental shelf; and 4) provide supporting wave data and model hindcasts to other Office of Naval Research Ripples DRI investigators for collaborative studies of the sea floor morphology response to wave events.

SUMMARY: The Martha’s Vineyard Experiment, focused on seafloor ripples excited by the orbital motion of ocean surface waves, took place during the fall of 2007. Researchers deployed an array of wave measuring instruments to observe in detail the wave evolution across the inner continental shelf and provide the hydrodynamic forcing conditions for collaborative studies of the coupled wave-morphology dynamics. The array spanned a 5 km distance from 8- to 24-m depth, including the dynamic inner-shelf region. Two Datawell Directional Waverider buoys were deployed along the deeper part of the transect in 24 and 20 m depth. In the middle of the transect an 8-element, coherent array of bottom pressure transducers was deployed in 18-15 m depth to provide detailed measurements of the two-dimensional wave group structure. At the shallow end of the transect, six bottom tripods with an acoustic Doppler velocimeter and an acoustic Doppler profiler (each also containing a pressure transducer) provided near-bed velocity measurements and surface-wave directional spectra. The tripods were deployed along the 10- and 12-m isobaths in fine and coarse sediment patches to study the effect of the heterogeneous sediment environment on the wave-seafloor interactions. The sensor locations were coordinated with the deployment of other tripods by Peter Traykovski (WHOI), Alex Hay (Dalhousie University), and Chris Sherwood (USGS) that were equipped with a variety of seafloor mapping instruments in addition to surface wave sensors. Preliminary analysis of the observations showed that during energetic events with predominantly onshore wave propagation directions, the observed wave heights at the shallowest sites were consistently smaller by about 15-25% than those observed at the deepest site, suggesting appreciable bottom-friction effects over this relatively short (about five kilometers) distance. Quantitative estimates of dissipation rates will be made based on the array observations and a two-dimensional wave propagation model that accounts for shoaling and refraction effects. These estimates, together with seafloor roughness measurements collected by other investigators, will be used to test parameterizations of bottom friction. The Martha’s Vineyard dataset will also be used to test new models for nonlinear wave evolution in variable depth (Janssen, et al., 2008; Janssen and Herbers, 2008).

PUBLICATIONS:


KEYWORDS: Ocean Surface Waves, Continental Shelf, Nearshore Processes
THE AUTONOMOUS WIDE APERTURE CLUSTER FOR SURVEILLANCE
John E. Joseph, Research Associate
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: The Autonomous Wide Aperture Cluster for Surveillance (AWACS) is a multi-disciplined team effort comprised of a number of collaborating academic and scientific institutions, fleet operation support communities, and manufacturers of ocean sensors and platforms. The long-term objective of the AWACS program is to develop an undersea surveillance system consisting of a cluster of autonomous vehicles for use in complex, littoral, shallow-water environments. The vehicles will be capable of sampling oceanographic, bottom, and acoustic features in a local environment and, as a networked cluster, will collectively feed adaptive sampling and search algorithms, leading to improved detection, classification, and localization of quiet targets.

The Naval Postgraduate School (NPS) contribution is focused on development, implementation, and validation of a quasi-real-time environment, transmission and ambient noise estimation system that assimilates data retrieved by the cluster of vehicles to recursively improve estimates of ocean, bottom, and acoustic parameters with reduced error variances in the volume of interest, thereby improving probability of detection while reducing false alarm rates.

SUMMARY: This multi-year program is based on an extensive build-test-build approach in which AWACS components and algorithms are designed, built, tested, and evaluated; then redesigned and rebuilt based on test results. The NPS effort in 2008 built upon the previous year’s effort to produce an improved estimation system built on a platform using commonly available PC components and software. The physical system is portable and well-suited for sea-based or land-based operations, wherever sufficient bandwidth for data transfer is available for near-real-time assimilation. The system is designed to handle data generated from a variety of ocean sensors provided the data are geo-referenced by latitude and longitude coordinates and time-stamped. During the New England Shelf Test 2008 (NEST08), environmental data were routinely assimilated, providing range-dependent sound-speed profiles and directional TL predictions used in daily acoustic experiments. New interfaces were employed and improved algorithms were applied that generated directional TL predictions in near-real-time to support the upcoming daily experiment. Improved geo-acoustic modeling was also employed to provide optimal TL estimates.

Work has commenced to incorporate ocean ambient-noise estimates to improve the value of guidance products. NPS has established a small Automatic Identification System (AIS) network along the central California coast using commercial, off-the-shelf receivers to begin analysis of ambient noise variability with shipping traffic over a moored hydrophone off Point Sur. A feed has been established from the Department of Transportation MSSIS system, which provides much wider area AIS coverage. These data will help establish shipping statistics in support of noise prediction in various regions of interest.

KEYWORDS: Littoral, Acoustics, Surveillance, Autonomous Underwater Vehicle, Anti-Submarine Warfare, Ambient Noise

THE DEVELOPMENT OF A REAL-TIME SIGNAL-TO-NOISE RATIO ESTIMATION SYSTEM (FOR PLUS INP)
John E. Joseph, Research Associate
Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: A persistent surveillance system can adjust to changing acoustic environments to improve overall performance by adapting search and sampling schemes such that the system is always optimizing probability of detection (PD) while minimizing the probability of false alarm (PFA). In challenging environments, signals from quiet targets can easily be masked by ambient noise (AN). To be effective, adaptation of search and sampling schemes should strive to maximize the directional signal-to-noise ratio (SNR) within the context of other operational constraints. The primary objective of this effort is to build
and test a near-real-time SNR estimation system that supports a persistent surveillance system consisting of mobile sensors operating in a challenging ocean environment. The output of the system will be 3D fields of SNR estimates that can be used to develop a cost function for an optimization algorithm to provide guidance to mission planners and operators in making adaptive search and sampling decisions and fed to a surveillance system to optimize system performance. The specific technical objectives are:

- To develop methods and algorithms for extracting ambient-noise information from available resources at a mission control site for assimilation into an ambient-noise estimation system. Resources may include (but are not limited to) satellite information, commercial shipping traffic data, meteorological data, information returned through the AUV surveillance network, and other sources, including intelligence information.
- To develop algorithms for assimilating directional ambient-noise data into a 3D gridded field providing a depiction of the current ambient-noise environment in a small shelf-break region.
- To develop algorithms that can derive 3D directional SNR fields for scenarios that consider a potential target, with expected acoustic characteristics and distribution density being detected with a passive receiver array operated over a range of bearings in a surveillance region of interest.
- To build scalability into the system to cover larger areas with sufficient resolution to support persistent surveillance operation in real-time.
- To provide measures of uncertainty associated with ambient noise and SNR estimates based on the age, location, and source of assimilated data (including climatology).

SUMMARY: This effort is one component of a much larger and more comprehensive program known as the Persistent Littoral Undersea Surveillance Innovative Naval Prototype (PLUS INP). PLUS INP is a multi-year multi-agency project involving research efforts at several educational institutions, Navy labs, and small businesses. PLUS INP uses an integrated team approach, which has resulted in various levels of collaboration in this project.

The NPS effort in 2008 focused on extending the work done under the AWACS program and developing methods for accurate directional-noise predictions. Comparisons of AIS data collected at NPS with the Navy’s historical shipping database show that there are areas with large differences in the “expected versus actual” shipping density, which would result in a significant difference in shipping noise prediction. Analysis is ongoing to determine accurate methods for including AIS data and data from other methods of ship tracking into a noise-prediction system.

COLLABORATIVE RESEARCH: RIP CURRENT DYNAMICS IN A COMPLEX BEACH ENVIRONMENT
James H. MacMahan, Assistant Professor
Timothy P. Stanton, Research Associate Professor
Jim Kirby,
Ad Reniers,
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To participate in a comprehensive European field experiment aimed at understanding nearshore circulation associated with rip current morphology. This beach featured an energetic wave climate, strong tidal modulation, and a typically complex beach platform composed of crescentic bars, rip channels, and an inter-tidal zone with ridge and runnel systems. To examine the nearshore mixing, mean flow patterns, sediment transport, and bathymetric coupling of low-frequency rip-current pulsations through observations and advance numerical modeling.

SUMMARY: In March-April 2008, the research team (three principal investigators, eight graduate students, one technician) participated in the field experiment at Truc Vert, France. Eight co-located pressure and electromagnetic current meters were deployed in a coherent, lagged, alongshore array, and two acoustic Doppler current profilers in a cross-shore array, all cabled to shore. Eight drifter-deployments were performed, spanning 2km in the alongshore to measure rip and alongshore currents. The research
team assisted the French in collecting beachface and subaqueous bathymetric surveys. Owing to the macro-tides (>4m), the rip current morphology was completely dry during spring low tides, which made installing and retrieving instruments feasible on this rip-current-dominated beach. Six major storms occurred; two storms had ~6m wave heights, resulting in a significant change in morphology. The data is still being quality controlled, as the experiment ended 15 April 2008. Preliminary observations illustrate that small bathymetric and tidal variations can generate surf zone eddies and rip currents. At low tide, strong alongshore currents owing to obliquely incident waves were observed, but as the tide rose and breaking patterns changed, the circulation pattern became more rip-current-dominated. It was found that the morphology was relatively (un) stable for spring (neap) tides as the rapid (moderate) changes in water level caused flow patterns to continuously adjust. Many of the drifters were retained within the surf zone during rip current activity and only episodic rip current bursts would remove them. During alongshore current conditions, the drifters did not exit the surf zone. This suggests that rip currents are a primary mechanism for cross-shore exchange.

PUBLICATIONS:


PRESENTATIONS:


THESIS DIRECTED:


DRI: LAGRANGIAN ESTUARINE AND RIVERINE FIELD OBSERVATIONS

James H. MacMahan, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research, Coastal Geosciences Group

OBJECTIVE: To obtain synoptic maps of velocities within the Skagit, Washington, system at various tidal levels. These velocity estimates will be compared with Arete’s Associates AROSS airplane surface-derived velocity estimates. In addition, drifter-derived dispersion and diffusivity will be estimated at various estuarine/riverine configurations within the macrotidal environment. This study will be integrated into concurrent observational programs of the tidal flat system and predictive modeling efforts.

SUMMARY: The research team (MacMahan, Thornton, Swick, and Wyckoff) performed eight drifter deployments in the Skagit River, Skagit marsh channels, and Skagit macrotidal flats between 23-28 September 2008. MacMahan, Cowen, and Lambert built a riverine drifter, which was modified from the
design of MacMahan, et al. [2008], and consisted of a central tube of 0.5 m long, 0.1 m diameter PVC and a 0.3 m long antenna mast of 0.03 m diameter PVC rising from the top. The drifters were weighted so that only the central tube was in the water. The riverine drifter was reduced in size, allowing for easier transport (shipping, within the boat, and carrying out to the flat). The drifters were tracked by internally recording, (0.5 Hz) hand-held GPS units that, after modification, have an absolute, dynamic position and velocity error of 0.4 m and 0.01 m/s [MacMahan, et al., 2008]. Drifters were released successfully in clusters or in a linear across-channel array of 8-20 drifters in the Skagit system. Once released, the drifters were allowed to migrate freely until they exited the area of interest, where they were removed from the water. Drifters were then re-released upstream or in a new location. Drifters would occasionally get caught along the channels. The number of cluster deployments varied on the macrotidal conditions. Drifters were released in the Skagit River, the North Fork of the Skagit River, the marsh channel near Craft Island, and on the tidal flat near Craft Island. A total of eight different drifter deployments were performed over six days.

PRESENTATION:


THESES DIRECTED:


DRI: LAGRANGIAN ESTUARINE AND RIVERINE FIELD OBSERVATIONS
James H. MacMahan, Assistant Professor
Department of Oceanography
Sponsor: Technical Service Agreement University of Delaware–Delaware Department of Transportation

OBJECTIVE: To monitor the scour-hole edge seaward of the Indian River Inlet Bridge piers. MacMahan (Naval Postgraduate School (NPS)) and Puleo (University of Delaware) propose to install two 200 kHz Marine Electronics 3D Profiling Sonars and RDI ADCPs to monitor the bed and currents adjacent to the seaward bridge piers and the scour-hole edge in near-real-time. Puleo is responsible for the 3D profiling sonars and MacMahan/Wyland are responsible for RDI ADCPs. Sonars and ADCPs will be connected to stainless steel mounts (designed by Puleo and deployed by contract divers) attached to the bridge piers approximately five to ten feet below the low water line. The mounting material will be 1.5 to 2-inch round stock to increase durability and strength. The ADCP will be mounted along the side of the mount. Having both sensors for each sensor pair attached to the same mount will increase deployment speed and reduce the number of objects to be affixed to the piers. MacMahan/Wyland will assist with deployment scheme and mounting set-up. MacMahan/Wyland are responsible for the purchase (through the University of Delaware), sensor integration, wireless networking, and for ADCPs. Once the sensors are installed, Puleo and MacMahan are responsible for developing algorithms that automatically synthesize the large sensor data streams, configure the data into viewable plots, and transition the data to a secure web page. Sonar data will be used to develop bathymetry maps and bathymetry-change maps so the day-to-day, pre-/post-storm and longer-term variability of the bottom within the view of the sonars can be quantified. Current meter data will be used to determine the average velocity profile and provide indications on the tidal flux between the bridge piers and correlated to the bathymetric evolution.

SUMMARY: MacMahan provided technical expertise and guidance in building an ocean surveying system (OSS) and provided specifications for the OSS via email and phone conversation with Jack Puleo and Jesse Hayden. Last year, Jesse Hayden visited NPS to see the NPS ocean surveying system. The University of Delaware’s OSS is close to completion, and MacMahan will provide additional assistance.
with data integration, quality control, and presentation. Time depending, MacMahan may visit the University of Delaware in January/February 2009.

PRESENTATIONS:


THESIS DIRECTED:


AOMIP: SYNTHESIS AND INTEGRATION ACTIVITIES TO IMPROVE MODELS AND REDUCE UNCERTAINTIES IN MODEL PREDICTIONS

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The Arctic Ocean Model Intercomparison Project (AOMIP) is an international effort to determine the systematic errors in models of the Arctic Ocean forced with realistic atmospheric conditions. AOMIP involves the international ocean-modeling community in a major test and intercomparison of model performance. The main goal of this project is to examine the behavior of different models, their ability to simulate past, present, and future variability of the Arctic Ocean climate, and the major processes maintaining ocean dynamics. Recent environmental changes in the Arctic Ocean present great challenges to the U.S. Navy and the Departments of Defense and Homeland Security. This project will advance understanding of past and present changes and prediction of future environmental change in the Arctic.

The AOMIP is a multi-year project, but the current funding started in the second half of 2008. Its major activities will include:

• Synthesis – to identify consistent errors across models, propose solutions, and find the most suitable and reliable coupled ice-ocean models for use in fully coupled regional and global climate models;
• Process Studies – to improve models, investigate processes using model results and observations. Another AOMIP contribution will be in regional Arctic-climate modeling via collaboration with regional and global climate modeling communities;
• Climate Change – 50-year experiment under “observed” forcing and 100-year experiment under reconstructed forcing;
• Interaction of Global and Arctic – AOMIP global models will be used to conduct numerical experiments to reveal interactions of the Arctic Ocean with global oceanic and atmospheric changes. The major contributors of the global change in changes of Arctic environment are changes associated with atmospheric conditions and changes brought to the Arctic with the Atlantic water. The latter was the major topic of recent AOMIP studies, and AOMIP will continue working with the Atlantic water role in the Arctic and global climate interaction;
• Fresh Water and Heat – to answer the fundamental questions: how does the fresh water/heat enter the Arctic Ocean system? How does it move about (which includes undergoing phase changes) and how does it finally exit the system? This theme also includes the influence of fresh water/heat on the ocean overturning.
These research themes specifically address the emphasis area in the ARCSS NSF 06-603 solicitation: to resolve the major program question of what changes in the Arctic system imply for the future; to understand the behavior of the Arctic system—past, present, and future; and to understand the role of the Arctic atmosphere, ice, and ocean as components of the global system.

PRESENTATION:

Maslowski, W., “Rate and Future Projection of Arctic Climate Change – An Update,” First International Symposium on the Arctic Research, Tokyo, Japan, 4-6 November 2008.

COLLABORATIVE RESEARCH: ENVIRONMENTAL VARIABILITY, BOWHEAD WHALE DISTRIBUTIONS, AND IÑUPIAT SUBSISTENCE WHALING – LINKAGES AND RESILIENCE OF AN ALASKAN COASTAL SYSTEM

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To identify and understand the complex linkages, mechanisms, and interactions within and between the atmosphere, ocean, and human components of the physical-biological-human system of the northern Alaska coast. The response and resilience of both these components and the system as a whole to variable forcing by external environmental change is being investigated.

SUMMARY: This research focused on contributing to the following four distinct (yet highly interrelated) approaches to understanding the system, including: 1) biological and physical ocean modeling to identify mechanisms of frontal and eddy formation and plankton aggregation, to describe the effects of environmental forcing from outside on the local ocean, and to understand longer-term, past and future variability in outside forcing on whaling success, 2) high-resolution field sampling to demonstrate the presence of physical features and associated biological concentrations and to validate modeling, 3) an assessment of the resilience and vulnerability of the subsistence hunting economy and culture in Barrow, and 4) a retrospective analysis synthesizing modeled ocean and climate conditions with available information on whale location, feeding, and harvest success to assess the resilience and vulnerability of the whale-ocean-human system to environmental change. Researchers completed an ensemble (4 times 25-year each) of coupled, pan-Arctic model runs configured at the 9-km and 45-level grid using realistic 1979-2004 ECMWF daily atmospheric forcing with varying surface heat and buoyancy fluxes. A robust accelerated trend is demonstrated in the reduction of summer sea-ice cover, which is most dramatic in the western Arctic Ocean/southern Beaufort Sea during the late 1990s and 2000s. Model output demonstrates that the reduction of sea-ice extent is accompanied by an even greater reduction of mean sea-ice thickness and total sea-ice volume. It is found that in addition to the atmospheric forcing, the oceanic advection of warm from the Bering/Chukchi Sea plays an important role in the overall decrease of summer sea-ice cover in the western Arctic Ocean. Both types of forcing and the resulting sea-ice melt are further amplified by the ice albedo feedback.

The research team developed a website for SNACS, which includes basic information about the project and presents model results and their analyses (www.oc.nps.navy.mil/NAME/name.html). In addition, the model climatology “atlas” of ocean circulation and hydrography for the SNACS region for 1979-2004 was developed and made available on the SNACS website, and hardcopies were distributed to other SNACS co-investigators and interested local communities and other institutions.

This project is complementary to and leveraging the project entitled: Developing an Understanding and Predictive Capability of the Interconnections among Arctic Terrestrial, Atmospheric, and Marine Systems. The above findings and following publications apply to both projects.

PUBLICATIONS:


**PRESENTATIONS:**


Maslowski, W., “Warming Arctic Climate – Causes, Changes, and Impacts,” Center for Computational Sciences, Tsukuba University, 28 October 2008 (invited).


**A COMPREHENSIVE MODELING APPROACH TOWARDS UNDERSTANDING AND PREDICTING THE ALASKAN COASTAL SYSTEM RESPONSE TO CHANGES IN AN ICE-DIMINISHED ARCTIC**

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

**OBJECTIVES:** This research combines state-of-the-art regional modeling of sea-ice, ocean, atmosphere, and ecosystem to provide a system approach to advance the knowledge and predictive capability of the diverse impacts of changing sea-ice cover on the bio-physical marine environment of coastal Alaska and over the larger region of the western Arctic Ocean. The focus on seasonally ice-free Alaskan coasts and shelves is in direct support of the “Coastal Effects of a Diminished-Ice Arctic Ocean” and littoral studies of interest to the U.S. Navy. Given the continued warming and summer sea-ice cover decrease in the Arctic during the past decades, this research has broad and long-term impact by facilitating studies of the potential increase in exploration of natural resources along the seasonally ice-free northern Alaskan coasts and shelves and of the use of northern sea routes from the Pacific Ocean to Europe. Such activities will change the strategic importance of the entire pan-Arctic region. The research will allow a better understanding of and planning for current and future operational needs in support of the continued U.S. commercial and tactical interests in the region.

**SUMMARY:** The Naval Postgraduate School (NPS) group has developed bathymetry, initial and forcing fields for an eddy resolving configuration. The model at 1/48-degree has started the spinup integration, which will continue through 2009 and beyond, subject to the availability of large amounts of computer resources and model performance on new computer systems becoming available this year (ARSC/XT5 and NPS/Sun Cluster). Early results imply that eddies with a radius of order 15 km commonly exist along the northern Alaskan shelf and slope in the Chukchi and Beaufort Seas. In addition, the significantly narrower and stronger boundary current along the continental slope is simulated with the width between 60 km and 80 km, which is less than the size of one grid-cell in many global ocean models.

Research analyses were performed toward understanding oceanic circulation and mechanisms contributing to the recent warming in the western Arctic Ocean (Maslowski and Clement Kinney, 2009). In particular, the thermodynamic coupling at the ice-ocean interface in the western Arctic Ocean has been investigated. It was demonstrated that the excess oceanic heat that in recent years has been accumulating
below the surface during summer might be a critical initial factor in reducing ice concentration and thickness in the western Arctic Ocean at the early melting season and onwards the following year.

PUBLICATIONS:


PRESENTATIONS:


DEVELOPING AN UNDERSTANDING AND PREDICTIVE CAPABILITY OF THE INTERCONNECTIONS AMONG ARCTIC TERRESTRIAL, ATMOSPHERIC, AND MARINE SYSTEMS

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: SDSU/National Science Foundation

OBJECTIVE: The three scientific goals that address the merit of this project are to: 1) estimate the historic and future impacts of variability within the ocean and atmospheric systems on terrestrial fluxes of gaseous and non-gaseous materials and energy between the land and the atmosphere and sea; 2) evaluate the impacts of variation in radiation, climate, ocean circulation, ocean temperature, and sea-ice position and extent on terrestrial processes, including those that have feedback on atmospheric and ocean processes; and 3) provide high-resolution products and datasets, relevant to the patterns and controls of terrestrial and oceanic processes, for use in other projects.

SUMMARY: Research focused on analyses of high-resolution, regional, coupled ice-ocean model output to assess sea-ice extent and relevant to sea-ice variability oceanic processes, to address the global climate model limitations, and to understand the past and present ice and ocean conditions in the Arctic Ocean. An ensemble (4 times 25-year each) of coupled, pan-Arctic model runs configured at the 9-km and 45-level grid was completed using realistic 1979-2004 ECMWF daily atmospheric forcing with varying surface heat and buoyancy fluxes. A robust, accelerated trend is demonstrated in the reduction of summer sea-ice cover, which is most dramatic in the western Arctic Ocean/southern Beaufort Sea during the late 1990s and 2000s. Model output demonstrates that the reduction of sea-ice extent is accompanied by an even greater reduction of mean sea-ice thickness and total sea-ice volume. It is found that in addition to the atmospheric forcing, the oceanic advection of warm from the Bering/Chukchi Sea plays an important role in the overall decrease of summer sea-ice cover in the western Arctic Ocean. Both types of forcing and the resulting sea-ice melt are further amplified by the ice albedo feedback.

A new version of the 9-km and 45-level pan-Arctic coupled ice-ocean model was developed, including improved physics, thermodynamics, and numerical optimizations, which is currently run in a spin-up mode.
in preparation for a multi-decadal integration forced with realistic ERA-40 data. A website for SNACS was also developed, which includes basic information about the project and presents model results and their analyses (www.oc.nps.navy.mil/NAME/name.html). In addition, the model climatology “atlas” of ocean circulation and hydrography for the SNACS region for 1979-2004 was developed and made available on the SNACS website, and hardcopies were distributed to other SNACS co-investigators and interested local communities and other institutions.

This project is complementary to and leveraging the project entitled: Collaborative Research: Environmental Variability, Bowhead Whale Distributions, and Inupiat Subsistence Whaling - Linkages and Resilience of an Alaskan Coastal System. The above findings and following publications apply to both projects.

PUBLICATIONS:


PRESENTATIONS:


Maslowski, W., “Warming Arctic Climate – Causes, Changes, and Impacts,” Center for Computational Sciences, Tsukuba University, 28 October 2008 (invited).


TOWARDS ADVANCED UNDERSTANDING AND PREDICTIVE CAPABILITY OF CLIMATE CHANGE IN THE ARCTIC USING A HIGH-RESOLUTION, REGIONAL ARCTIC CLIMATE SYSTEM MODEL

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: Department of Energy

OBJECTIVE: This is a collaborative project involving principal investigators from four institutions: the Naval Postgraduate School (lead institution, PD/PI – Wieslaw Maslowski); the University of Colorado in Boulder (co-PI – John Cassano); Iowa State University (co-PI – William J. Gutowski); and the University of Washington (co-PI – Dennis P. Lettenmaier). The following report is a summary of up-to-date progress at all the above institutions and their collaborators. This SciDAC/CCPP grant is funding efforts to advance the science of climate change and prediction in the Arctic region. Its primary goals are to develop a state-of-the-art Regional Arctic Climate system Model (RACM), including high-resolution atmosphere, land, ocean, sea ice, and land hydrology components; and to perform multi-decadal numerical experiments using high-performance computers to minimize uncertainties and fundamentally improve current predictions of climate change in the northern polar regions. These goals are realized first through evaluation studies of climate system components via one-way coupling experiments. Simulations are used to examine the effects of advancements in climate component systems on their representation of main physics, time-mean fields and to understand variability signals at scales up to decades. As such, this research directly addresses some
of the major science objectives of the BER Climate Change Research Division (CCRD) regarding the advancement of decadal-to-centennial climate prediction.

**SUMMARY:** The research team focused on coupling each climate model component to the common NCAR flux coupler and addressed the general circulation model (GCM) limitations in predicting Arctic climate through the identification of physical and numerical requirements of future GCMs. Later stages of this project will also determine and quantify the coupled Arctic climate system processes responsible for the recent observed and future projected changes in the ice pack, regional hydrological cycle, and freshwater export into the North Atlantic; and assess decadal system scenarios of a seasonally/partially ice-free Arctic Ocean, including their timing.

All personnel involved in the development of a regional climate system model attended dedicated project workshops, the first in San Francisco (14-15 December 2007), the second in Boulder (15-16 May 2008), and the third in Seattle (5-6 December 2008). All principal investigators (PI) also attended the DOE CCPP program meeting in Indianapolis (17-19 September 2007) and the Arctic System Model meeting organized by the International Arctic Research Center in Boulder (19-21 May 2008).

**Comparison of NCAR/CCSM3 Oceanic Fluxes with NPS Model and Observations**

In order to evaluate global climate model prediction of warming and summer ice-free summers in the Arctic Ocean, results from two ensemble members of NCAR-CCSM3 IPCC/AR4 runs on northward oceanic heat advection from the North Atlantic and the North Pacific were compared. The CCSM3 simulations were compared to estimates of oceanic heat fluxes from the NPS ice-ocean model and from observations. It was concluded that compared to the high-resolution NPS model and estimates from observations, CCSM3 simulations; have too weak northward heat fluxes through the Bering/Chukchi Sea, which explains why there is too much sea-ice in the western Arctic; have too strong ice export from the Arctic Ocean and too weak northward and recirculating fluxes at Fram Strait, which together results in too much ice in the Greenland Sea; simulate too much volume and heat flux through the Barents Sea, which results in too much sea-ice melt in the eastern Arctic; and are too conservative in representing past and present and predicting future ice-melt because the melt of sea-ice in those simulations originates in the eastern basin, where ice converges and thus reduces the ice albedo effect, which takes longer to melt all the sea-ice in summer.

**CPL7/CCSM4**

In late 2007, a copy of the NCAR CCSM3 flux coupler (CPL6) was distributed among the project participants in order to advance progress on coupling each climate model component using the same common code. In early May 2008, the research team obtained a copy of a working version of the NCAR new flux coupler (CPL7) to become a part of the CCSM4 release. A strategic decision was made to switch to the new coupler, especially since CPL6 is not going to be supported by NCAR once CPL7 is publicly released. Through collaboration with Tony Craig at NCAR, Gabriele Jost (HPCMP) and Jaromir Jakacki (IOPAN) have ported the code and successfully tested it on the computers at the Arctic Region Supercomputing Center. Test experiments are being set up with a single “active” component coupling to CPL7, subject to access to other NCAR climate component codes, such as POP and CICE.

A test version of a Live Access Server (LAS) has been built for RACM by Dr. Jaromir Jakacki (IOPAN) and is currently under evaluation. Feedback from other project participants will be used to further expand the LAS and make it more automated and user friendly. It is expected that this tool will become significantly useful for wide distribution and analyses of output from both one-way and fully coupled climate model runs.

The RACM project website has been created at [www.oc.nps.edu/NAME/name.html](http://www.oc.nps.edu/NAME/name.html); the site includes basic information about the project, the people involved, meetings, presentations, and relevant publications and communications.

**PUBLICATIONS:**


**PRESENTATIONS:**


**TOWARDS A HIGH-RESOLUTION, GLOBAL, COUPLED CLIMATE SYSTEM FOR PREDICTION ON DEcadal/CENTENNIAL SCALES**

* Wieslaw Maslowski, Research Associate Professor
* Robin T. Tokmakian, Research Associate Professor
* Albert J. Semtner, Jr., Professor
* Department of Oceanography
* Sponsor: Department of Energy

**OBJECTIVE:** The CCPP grant to the Naval Postgraduate School is funding efforts to advance the science of decade-to-century climate prediction. Its primary goal is to understand aspects of global and regional climate variability and climate change and to evaluate and improve how they are simulated on scales through centennial in numerical simulations using “cutting edge” dynamic atmospheric, ocean, and ice models. Simulations of the coupled ocean/ice system (Parallel Ocean Program (POP) and CICE ice models from LANL) are being used to examine the effects of model advancements of ocean/ice systems on the representation of time-mean fields and to understand the ocean’s variability signals on scales up to decades. As such, the research team is advancing decadal-to-centennial climate prediction, a major science objective of the BER Climate Change Research Division.

**SUMMARY:** Simulations of the coupled ocean/ice system (Parallel Ocean Program (POP) and CICE ice models from LANL) are being used to examine the effects of model advancements of ocean/ice systems on the representation of time-mean fields and to understand the ocean’s variability signals on scales up to decades. Among those runs, high-resolution, regional, Pan-Arctic, coupled ocean/ice model integrations focus on the representation of decadal variability in the northern high-latitude oceans and further test ocean/ice parameterization improvements for use in global climate models. The 9-km coupled ocean and sea-ice model of the Pan-Arctic region has been integrated for ~150 years so far, including a 48-year spin-up and an ensemble of four interannual runs forced with 1979-2004 realistic, atmospheric, forcing fields from ECMWF. The main focus of these analyses has been on understanding the causes and rates of the recent Arctic sea-ice reduction. It was found that the multi-year sea-ice pack in the Arctic Ocean
significantly decreased in the late 1990s and 2000s, suggesting an accelerated warming trend in the northern polar climate. Model results show good agreement with satellite observations of sea-ice extent and imply much greater reduction of sea-ice thickness and volume than ice extent. The ongoing analyses attribute some of the recent change of sea-ice cover to increased advection of heat from the Bering Strait through the Chukchi Sea into the Beaufort Sea, where a major reduction of sea-ice cover has occurred. The ocean circulation and fluxes of water mass and properties through the northern Bering Sea determine downstream conditions over the Chukchi/Beaufort shelves and in the central Arctic Ocean. However, the Bering Strait region represents several challenges to modelers, especially at a horizontal resolution insufficient to explicitly resolve the width of the strait. Use of a high-resolution (1/12° or ~9km) model and a large-enough spatial domain allows for realistic representation of flow through the narrow and shallow straits in this region. In addition, results indicate the increased recirculation of Atlantic water within the Fram Strait region as a potential cause of the removal/melt of sea-ice over the Greenland shelf. The sea-ice melt and the upper-ocean circulation patterns act to increase the freshwater content of the Arctic Ocean; a buildup with potentially important consequences to the thermohaline circulation of the North Atlantic, if this freshwater is released out from the Arctic Ocean.

**PUBLICATIONS:**


**PRESENTATIONS:**


Maslowski, W., “Rate and Future Projection of Arctic Climate Change – An Update,” First International Symposium on the Arctic Research, 4-6 November 2008.


Maslowski, W., “Warming Arctic Climate – Causes, Changes, and Impacts,” Center for Computational Sciences, Tsukuba University, 28 October 2008 (invited).


THESIS DIRECTED:


TOWARDS PREDICTION OF ARCTIC SEA ICE–OCEAN–GLOBAL CLIMATE INTERACTIONS AT SEASONAL-TO-DECADAL SCALES

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: NASA Goddard Space Flight Center

OBJECTIVES: The NASA grant is funding efforts to advance the science of seasonal-to-decadal variability and prediction of the Arctic climate and its interactions with the global climate. Its primary goal is to understand aspects of Arctic climate variability and change; and to evaluate and improve how they are simulated on scales through decadal using “cutting edge” dynamic ocean and ice models forced with realistic atmospheric data. The coupled ocean/ice system has been used to focus on the representation of decadal variability in the northern high-latitude oceans. As such, we are advancing studies of the role of sea-ice and decadal variability and prediction of sea-ice and ocean states in the Earth system, a major science objective of the NASA Earth System Enterprise research. The main focus of this research has been on understanding the causes and rates of the recent Arctic sea-ice reduction.

SUMMARY: The multi-year sea-ice pack in the Arctic Ocean significantly decreased in the late 1990s and 2000s, suggesting an accelerated warming trend. Model results show good agreement with satellite (SSMI) observations of sea-ice extent and imply a much greater reduction of sea-ice thickness and volume than ice extent. The ongoing analyses attribute some of the recent change of sea-ice cover to increased advection of heat from the Bering Strait through the Chukchi Sea into the Beaufort Sea, where a major reduction of sea-ice cover has occurred. The ocean circulation and fluxes of water mass and properties through the northern Bering Sea determine downstream conditions over the Chukchi/Beaufort shelves and in the central Arctic Ocean. In addition, results indicate the increased recirculation of Atlantic water within the Fram Strait region as a potential cause of the removal/melt of sea-ice over the Greenland shelf (Stroeve and Maslowski, 2007). The research team collaborated with Dr. Jay Zwally on comparison and synthesis of the model results on sea-ice thickness with data from NASA’s ICESat program; and also collaborated with Dr. Ron Kwok of NASA/JPL on comparisons of sea-ice deformation fields derived from RGPS and
ice drift and export from SSMS. The first effort helps with validation of the recently adapted sea-ice model (CICE) with multi-category ice-thickness distribution to improve the realism of sea-ice conditions, especially in winter. The latter allows synthesis of effects of atmospheric and oceanic forcing on ice distribution and deformation in the Arctic Ocean, as well as its export through the Fram Strait and Barents Sea. Significant improvements in representation of sea-ice motion and deformation fields have been shown in the (CICE) sea-ice model. Realistic sea-ice features, resulting from the improved thermodynamics, can be compared against RGPS and ERS1/ERS2 observations.

PUBLICATIONS:


PRESENTATIONS:


AN ANALYSIS OF HF RADAR DATA FROM THE NORTHERN ADRIATIC SEA

Jeffrey D. Paduan, Professor
Department of Oceanography
Sponsor: CNR-ISDGM, Venice, Italy, and OGS, Trieste, Italy

OBJECTIVE: To work with Italian and NATO-sponsored research groups in the northern Adriatic Sea region to deploy and utilize high-frequency, surface-current mapping systems.

SUMMARY: This project utilized funding from the CNR Istituto di Scienze Marine (ISMAR), Venice, Italy, to support analyses of ocean-surface current maps offshore of the Venice Lagoon produced from a three-site, high-frequency (HF) radar network. Instrument siting and calibration were included, along with analysis of a year-long record of hourly surface-current maps. The maps showed patterns of tidal currents, low-frequency currents, and recurring sub-mesoscale (~5 km) eddies features offshore of the Malamocco Inlet. The project also supported the integration of these efforts with a second array of HF radar systems along the western Adriatic Sea and included support for a Ph.D. student at the University of Venice. During this year, the program extended eastward through a collaboration with Croatian scientists to cover the northeast Adriatic Sea.
OCEANOGRAPHY

PUBLICATION:

PRESENTATION:
Gačić, M., “Can We Use High-Frequency Radars for Study and/or for Early Meteorological Tsunami Warning?” International Symposium on Meteo Tsunamis, Vela Luka, Croatia, 19-21 June 2008.

KEYWORDS: HF Radar, Ocean Currents, Ecosystem Modeling, Cross Shore Exchange

THE COASTAL OCEAN CURRENTS MONITORING PROGRAM
Jeffrey D. Paduan, Professor
Department of Oceanography
Sponsor: State of California (via San Francisco State University)

OBJECTIVE: To demonstrate the viability of long-range high-frequency radar for mapping ocean currents out to 200 km from shore.

SUMMARY: This program is part of a multi-year, statewide project to instrument California with shore-based, high-frequency (HF) radar, ocean-current mapping systems and to develop a surf-zone transport-monitoring system. The project is working to extend the mapping network that originated in Monterey Bay to cover the entire state in order to provide real-time mapping of surface transport for hazardous spill mitigation and search-and-rescue operations, as well as archival support for dispersal-based management decisions. Professor Paduan and the Naval Postgraduate School are responsible for the installation and operation of 10 HF radar sites from the Big Sur coastline to Half Moon Bay, as well as the interpretation of surf-zone wave and current data. The overall project is a critical demonstration project in California and nationwide for the growing efforts to establish an integrated ocean observing system.

PUBLICATIONS:


OCEANOGRAPHY


PRESENTATIONS:


THESIS DIRECTED:


KEYWORDS: HF Radar, Ocean Currents, Air-Sea Interaction
CORE MOORING DATA SUPPORT
Jeffrey D. Paduan, Professor
Department of Oceanography
Sponsor: Monterey Bay Aquarium Research Institute

OBJECTIVE: To provide real-time quality-control feedback for physical oceanographic and meteorological observations being made on deep-ocean moorings in Monterey Bay.

SUMMARY: The specific activities of this sub-project involve data processing and quality assurance for physical oceanographic and meteorological sensors on real-time mooring platforms deployed in Monterey Bay. The moorings are maintained by the Monterey Bay Aquarium Research Institute (MBARI). Naval Postgraduate School personnel retrieve both real-time and post-recovery data from the sensors, quality control and reformat the data, and return the processed datasets to MBARI.

PUBLICATION:

KEYWORDS: HF Radar, Ocean Currents, Observing Systems

DELIVERY AND QUALITY ASSURANCE OF SHORT-TERM TRAJECTORY FORECASTS FROM HIGH-FREQUENCY RADAR OBSERVATIONS
Jeffrey D. Paduan, Professor
Department of Oceanography
Sponsor: NOAA Coastal Response Research Center (via San Francisco State University)

OBJECTIVE: To quantify errors in high-frequency (HF), radar-derived trajectory estimates and to document formats and procedures needed to effectively use those estimates within government oil-spill response agencies. This project was a joint effort between researchers at the Naval Postgraduate School (NPS) and San Francisco State University. The project will develop, assess, and document the use of real-time, ocean-surface current maps from HF radar installations. Specifically, the research team will evaluate the use of these data in support of oil-spill response activities. An extensive test of these capabilities was conducted in connection with the NOAA Safe Seas 2006 oil spill exercise offshore San Francisco in August 2006. The principal investigators (PI) intend to conduct a systematic post-exercise evaluation and document lessons-learned. The PIs also intend to quantitatively assess the performance of the short-term (24-hour), surface-current prediction methodology that was developed for the Safe Seas 2006 exercise by comparing observed and predicted currents under a wide range of environmental conditions. To aid that assessment, the research team will conduct a multi-day, multi-deployment, field experiment using an array of GPS-tracked surface drifters. Finally, the PIs intend to document results in the form of a package of recommendations and procedures for the integration of HF radar-derived products into real-time spill-response protocols.

PRESENTATIONS:

TECHNICAL REPORT:

THESES DIRECTED:


KEYWORDS: HF Radar, Ocean Currents, Oil Spill Response, Search and Rescue

CAREER: FLUXES AND STRUCTURES IN DOUBLE-DIFFUSIVE CONVECTION
Timour Radko, Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To conduct numerical simulations of oceanic thermohaline staircases and explain their dynamics. These experiments involve analysis of the acoustic scattering on the interfaces, a project of direct relevance to Navy research interests in general and to the interests of the Oceanography Department at the Naval Postgraduate School in particular.

This ongoing project is expected to take three months per year. Students participating include Ana Wilson, Ivo Prikasky, Stephen Wall, Shelley Caplan, and Greg Caro. Staff member Mike Cook will also participate.

COLLABORATIVE RESEARCH: STUDIES OF THE INFLUENCE OF THE ANTARCTIC CIRCUMPOLAR CURRENT ON THE ATLANTIC MERIDIONAL CIRCULATION
Timour Radko, Associate Professor
I. Kamenkovich, Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To conduct numerical simulations of oceanic thermohaline circulation in the mid-latitude Atlantic and in the Antarctic Circumpolar Current. The main goal of this modeling effort is to explain the role of the mesoscale variability in the dynamic connection of these two regions. Properties of the ocean thermal fronts and eddies determine undersea warfare (USW) tactics in areas of high mesoscale activity; therefore, efforts to predict its distribution and strength are directly related to Navy research interests in general and to the interests of the Oceanography Department at the Naval Postgraduate School in particular.

This ongoing project is expected to take two months per year. Students participating include Pierre-Ives Dare, Erick Edwards, and David Widener.
NUMERICAL STUDIES OF DOUBLE-DIFFUSIVE CONVECTION IN THE INTERIOR OF GIANT PLANETS
Timour Radko, Associate Professor
P. Garaud,
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: Theoretical and numerical modeling of double-diffusive convection under a variety of environmental conditions. This ongoing project is expected to take one month per year. The student participating in this research is Adrienne Traxler (UCSC), along with staff member Mike Cook.

COLLABORATIVE RESEARCH: BENTHIC LAYER GEOCHEMISTRY AND PHYSICS AT THE KILO NALU
Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: In this field project, the diffusivity of rippled, sandy, ocean beds forced by waves and currents is studied. Bed diffusivity controls the micro-particulate and geochemical fluxes between the sea bed and the ocean, and is strongly modulated by wave and current forcing above the bed. This project is a collaboration with geochemists, biologists, and ocean engineers at the University of Hawaii. The project uses a cabled observatory at Kilo Nalu (which is modeled on the Naval Postgraduate School MISO cabled observatory that has been maintained offshore of the campus for the last ten years).

SUMMARY: Software to extract the 3D bedform morphology timeseries surrounding the BCDVSP profiler was developed for the rapid scanned laser developed in the principal investigator’s research group; it was deployed at the Kilo Nalu experiment site during the 2007 experiment. Data from these two instruments were used to characterize the flow field, turbulence levels, and bed porosity above a rippled sandy bed. A new dye injection system deployed during the experiment was used to identify the preferred diffusive paths taken by fluid within the sand under ripple bedforms. Analysis of this comprehensive dataset is underway; some results were presented with colleagues at the March 2008 Ocean Sciences Meeting.

PUBLICATION:

PRESENTATIONS:

OBJECTIVE: Observations of vertical fluxes of heat, salt, and momentum between the ocean interior and surface are important for understanding and modeling the processes that maintain the perennial ice cover in the Arctic, particularly at a time of such rapid changes in ice coverage and volume. These changes have direct impact on strategic naval issues, since most climate models, which depend on improved, small-scale, physical parameterizations, show perennial ice cover disappearing in the next five to twenty years, opening trans-Arctic sea lanes and altering defense requirements in the region. This is a proposal to continue ocean flux deployments in the central Arctic and to extend deployment to the western Arctic in order to improve parameterizations of the complex ocean-ice-atmosphere processes in coupled models.

SUMMARY: Observations of upper ocean flux timeseries in the Arctic Basin continued this year with the deployment of four Naval Postgraduate School-designed Ocean Flux Flux Buoys (AOFB) in the Arctic Basin in collaboration with five other research groups. This program is a component of the International Polar Year, an international collaborative effort to intensively observe and model ocean/ice processes at high latitudes. These observations are being made at a time of significant change in ice cover and volume of the perennial Arctic ice pack, particularly over the last four years, which appears to be responding to global-warming climatic pressures. A paper reporting results from these buoy observations was published in the Journal of Geophysical Research, another paper summarizing summer heat fluxes near the North Pole was completed, and an analysis of the SHEBA Beaufort Sea CTD and microstructure dataset was accepted in the Journal of Geophysical Research.

PUBLICATIONS:


CONFERENCE PRESENTATIONS:


THESES DIRECTED:


**OCEAN-ICE INTERACTION IN THE AMUNDSEN SEA: THE KEYSTONE OF WEST ANTARCTIC STABILITY**

**Timothy P. Stanton, Research Associate Professor**
**William J. Shaw, Research Assistant Professor**
**Department of Oceanography**
**Sponsor: National Science Foundation, OPP**

**OBJECTIVE:** Integrated oceanographic and glaciological field studies are being linked with regional and local modeling activities to advance the ability to predict future behavior of ice sheets, particularly that portion of west Antarctica that drains into the Amundsen Sea. The Naval Postgraduate School (NPS) component of this large, collaborative project (including NASA and British Antarctic Survey participants) is to develop, deploy, and analyze data from a highly specialized, ocean-flux profiler that will operate in the ocean cavity below the 500m-thick Pine Island Glacier Ice Shelf. The profiler will measure turbulent fluxes of heat, salt, and momentum near the ice/ocean interface, and once each day will measure the ocean structure and lateral fluxes across the ocean cavity. The societal and naval importance of this research is the need to predict the future sea level that impacts all shore facilities and littoral regions. Without a process-based understanding of the interaction of the ocean on the ice sheet discharge, supported by measurements, and its incorporation into predictive models sea-level predictions, large errors will remain in sea-level-rise predictions.

**SUMMARY:** This year’s effort focused on the development and testing of the sub-glacial ocean profiler. Prototype buoyancy engines were assembled and successfully tested to over an 800m-equivalent depth in a newly developed, pressure-test facility. This buoyancy engine was then used to pressure cycle the custom-manufactured carbon fiber and titanium constructed profiler housing over the equivalent of two years of daily profiling, without any failures. Control and acquisition software has been advanced using the same data acquisition boards developed for the Ocean Flux Buoys, and a power control/junction electronics board was completed to interconnect the many components of this instrument system. The profiler is being prepared for tank and field tests in 2009. A supplemental proposal was written to add an ice shelf deployment in the Ross Sea late in 2009, since the main PIG deployment was delayed due to OPP logistic constraints. The principal investigators hosted a science and logistics workshop at NPS in December for the Pine Island Glacier Project, with participants from NASA, BAS, NYU, OSU, and UW attending.

**RCEX: RIP CURRENT EXPERIMENT ON THREE-DIMENSIONAL NEARSHORE CIRCULATION**

**Timothy P. Stanton, Research Associate Professor**
**James H. MacMahan, Assistant Professor**
**Edward B. Thornton, Distinguished Professor Emeritus**
**Department of Oceanography**
**Sponsor: Office of Naval Research Coastal Geosciences**

**OBJECTIVE:** To observe the 3D current circulation of rip channel/shoal systems in the nearshore. A combination of Eularian, Lagrangian, and remote sensing methods will be used by Naval Postgraduate School (NPS) faculty and collaborators at a site within Monterey Bay that maintains incised rip channels in the surf zone. A parallel modeling effort is extending the Delft 3D Nearshore Circulation Model to include vertical structure effects. This model is being transitioned as the new Navy surf-zone circulation model.

**SUMMARY:** Analysis of the spring 2007 observations of current circulation and boundary layer processes in Monterey Bay continued in 2008. The focus was on co-principal investigator James MacMahan’s drifter deployments, combined with the long-shore PUV array and cross-shore ADCP current profile array deployed across a rip-channel/shoal cell. The short-duration bottom-boundary-layer measurements were
analyzed to determine off-shore sediment transport rates within a rip channel. A major finding of this surf-zone circulation study was the presence of closed circulation cells with offshore flow in the rip channels, and nearly balanced onshore flow over the shoals.

**PUBLICATIONS:**


**PRESENTATIONS:**


**THESES DIRECTED:**


TOWARD A PREDICATIVE MODEL OF ARCTIC COASTAL RETREAT IN A WARMING CLIMATE, BEAUFORT SEA, ALASKA
Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research/NOPP

OBJECTIVE: To begin developing a predictive model of Arctic coastal dynamics that integrates retrospective analyses of remotely sensed and on-the-ground environmental data, new observations, and monitoring of inner-shelf and near-shore processes, and numerical models that explicitly address the feedbacks between landscape and seascape responses to climatic change in the Arctic. The Naval Postgraduate School (NPS) component will provide detailed wave observations cross-shelf at a location along Alaska’s northern coast over a two-year period. The resulting coastal model will help Navy wave prediction and coastal modeling efforts as the perennial ice cover in the Arctic Ocean continues to recede and increase wave-forced erosion of the fragile coastline.

SUMMARY: During year one of this project, four autonomous pressure sensor systems were fabricated using existing data logger electronics and pressure sensors. The systems are boat-deployable by one person, and can sample for up to four months at an 8Hz sample rate. These observations will be used to characterize wave transformation across the shallow, muddy, coastal shelf offshore from the rapidly eroding permafrost bluffs that are the focus of this project. While the sensors were readied and shipped to Alaska for an early summer deployment, heavy coastal ice cover prevented any of the boat survey or sensor deployments from occurring. The plan is to deploy later in summer 2009 to avoid a similar problem.
DEPARTMENT OF OCEANOGRAPHY

2008
Faculty Publications and Presentations
PEER-REVIEWED JOURNAL PUBLICATIONS


JOURNAL PUBLICATIONS


**NON-PEER-REVIEWED PROCEEDINGS PAPERS**


**CONFERENCE PUBLICATIONS**


**PRESENTATIONS**


Maslowski, W., “Rate and Future Projection of Arctic Climate Change – An Update,” First International Symposium on the Arctic Research, Tokyo, Japan, 4-6 November 2008.


Maslowski, W., “Warming Arctic Climate – Causes, Changes, and Impacts,” Center for Computational Sciences, Tsukuba University, 28 October 2008 (invited).


**CONTRIBUTED CONFERENCE PRESENTATIONS**


TECHNICAL REPORTS


DEPARTMENT OF PHYSICS

JAMES H. LUSCOMBE
CHAIR
OVERVIEW:
The Department of Physics has unique resources and faculty expertise in combat systems technologies, including sensor, acoustic, and weapon systems.

CURRICULA SERVED:
- Combat Systems Science and Technology
- Undersea Warfare
- Space Systems Engineering, Space Systems Operations
- Electronic Warfare, Information Warfare

DEGREES GRANTED:
Master’s and Ph.D. degrees in Physics, Applied Physics, and Engineering Acoustics

RESEARCH THRUSTS:
- Optical and Electromagnetic Signal Propagation and Detection
- Weapons and Weapons Effects
- Underwater Acoustics and Communications
- Physical Acoustics
- Free-Electron Laser Physics
- Accelerator Physics
- Railgun Technologies
- Explosive Detonation Physics
- Dynamic Materials Properties
- MEMS-Based Sensors and Nanotechnologies
- Novel Detector and Sensor Development
- Autonomous Robotics
- Remote Sensing
- Radar Imaging, Non-Cooperative Target Recognition
- Terahertz Radiation, Sources and Imaging
- Physics of Networks
- Quantum-Well Infrared Detectors
- Quantum Cascade Lasers

RESEARCH FACILITIES:
The Department of Physics has numerous advanced research facilities, including: a dedicated free-electron laser and linear accelerator facility; a gas gun laboratory; a railgun laboratory; a large acoustic anechoic chamber; underwater acoustic tank facilities; a class 1000 clean room; a sensors research lab (including a laser vibrometer, a Fourier transform infrared spectroscopy, and a low-temperature photocurrent measurement system); a dome for telescope systems; and several advanced electron microscopes (a JEOL scanning electron microscope with variable temperature cathodoluminescence and transport imaging capabilities, a NovelX scanning electron microscope, and a Nanonics atomic force microscope with near-field optical scanning capability).
The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Physics is provided below:
<table>
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OBJECTIVES: 1) To participate in the collection of linear and angular vibration data at selected locations on the PHALANX Block 1B Close-In Weapons System (CIWS) during live-fire testing to be conducted in FY08 at China Lake; 2) to analyze the vibration measurements using MATLAB and to report the results in a Naval Postgraduate School (NPS) technical report; 3) to create a DVD archive of the vibration measurements, including the raw data, the MATLAB code, and the technical report; 4) to participate in the collection of angular vibration data at selected locations on the PHALANX Block 1B CIWS during non-firing slewing testing to be conducted in FY08, either at China Lake or at Raytheon, Tucson, Arizona; 5) to analyze the angular vibration measurements using MATLAB and to report the results in an NPS technical report; and 6) to create a DVD archive of the vibration measurements, including the raw data, the MATLAB code, and the technical report.

SUMMARY: The live-fire testing planned in FY08 was postponed to FY09. A non-firing tracking exercise was conducted in April 2008. NPS did not participate in this testing, but did provide data analysis of the angular-rate sensor data that was taken. Analysis was also completed of linear and angular vibration measurements taken during live-fire testing conducted in June and July 2007, in which NPS participated.

TECHNICAL REPORT:


THESIS DIRECTED:


KEYWORDS: PHALANX, Close-In Weapons System, CIWS, Structural Dynamics, Vibration

OBJECTIVE: To examine the nature of radar image artifacts and their relationship to scattering model mismatch with radar measurements. To develop a generalized radar-imaging model that allows for arbitrary pulse shape and collection geometries (including moving targets).

SUMMARY: The research — now in its third year — has successfully developed a generalized radar-imaging theory appropriate to moving and stationary targets, multistatic radar environments, and general waveforms.

Moreover, the theory reduces to all known traditional, radar-imaging methods in the appropriate data limits.

The image quality for this approach has been characterized by a generalized image point spread function (PSF), which was shown to be related (in a non-trivial way) to the radar ambiguity function. Future work will concentrate on exploring the practical nature of this PSF.
DETONABLE LIQUID TECHNOLOGY FOR EXPLOSIVE ORDNANCE
DISPOSAL AND SAFE AND ARM
Ronald E. Brown, Research Professor
Jose Sinibaldi, Research Associate Professor
Department of Physics
Sponsor: Office of Naval Research

SUMMARY: A low-cost, precision shaped charge device for surgically neutralizing explosive ordnance was successfully demonstrated. This plastic-encased device at 25mm weighs less than 40 grams. It contains nitromethane, a flammable, organic liquid used commercially in fingernail polish removers, super-glue solvents, and race car fuels. It is sensitized in situ by the automated injection of an organic amine just prior to use, along with the insertion of a metal liner. It generates a hypervelocity jet powerful enough to penetrate through up to 60mm-thick steel casings and impact initiate explosive contents to either low- or high-order detonation based on computational modeling and experimental results against pure explosive.

Field tests conducted confirm the potential effectiveness of the neutralizer as an alternative to the use of large blocks of composition C-4 blocks to dispose explosive ordnance: 100 percent neutralization effectiveness was demonstrated against MK1 105mm projectiles and the Mk83 Mod4 1000 lb bomb in a series of tests conducted at the Naval Air Station in Fallon, Nevada.

These results concluded a three-year Office of Naval Research-funded research program. Discussions are currently underway with potential system integration establishments, particularly those with robotic products, to transition this technology for military and law enforcement applications.

THE EFFECTS OF HYDRO-REACTIVE JETTING (DISCLOSURE SENSITIVE)
Ronald E. Brown, Research Professor
Jose Sinibaldi, Research Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To develop a clearer understanding of the effect of chemical reaction during the hypervelocity impact of combustible jet-rods against submerged targets, and to apply the learning to enhancing the terminal performance of directed-energy warheads. Findings from over 20 hypervelocity impact tests show that interfacial reaction between aluminum and oxidized fluids (including water) during impact and penetration against steel targets can increase target damage as observed by displacement volume and deformation. A previously developed, segmented-erosion analytical model is employed to estimate the thermal baric conditions responsible for reaction and observed kinetics; in concert with ongoing collaboration with workers at the University of Illinois. Hypervelocity impact experimentation is conducted at the Ernst Mach Institute under a Naval Postgraduate School contract.

IMPROVING IMPERFORMANCE (DISCLOSURE SENSITIVE)
Ronald E. Brown, Research Professor
Department of Physics
Sponsor: Office of Naval Research

SUMMARY: This program exploits achievements in amplifying the detonation power of explosives experimentally demonstrated during the preceding. The detonation rate in a high-performance HMX-based explosive was increased by 34 percent, exceeding by 10 percent the fastest detonation rate from the most energetic pure compound made to date. Peak pressures were increased by four times. This technical
advance has broad application to explosive warhead technology. The design of an additional experiment for quantifying other terminal ballistic attributes of the experiment will be completed this year. This experiment will be conducted under a Naval Postgraduate School work-order to the Lawrence Livermore National Laboratory during 2009.

The primary objective of the current program is directed towards applying the technology to the initiation and power amplification of an extremely insensitive, low-energy, explosive formulation. The specific explosive under study cannot be initiated to detonation at charge diameters less than 180mm; requiring extremely high shock pressures. Work conducted in 2008 focused on deriving design parameters for an experiment that demonstrates the general applicability of the novel mechanism for initiating this new explosive. This work involved computational simulations of laboratory experiments using this explosive and other formulations of a similar nature for purposes of insuring valid technical bases for design and a complete charge design and experimental plan. The new design is predicted to detonate 40 percent faster than that from conventional initiation; matching that of pure CL-20, which is the fastest detonating explosive on the laboratory bench. This will be a new record for a highly diluted, aluminized explosive. Characteristics of the overall design also provide elements of safety and cost, in addition to those attributed to the explosive composition itself. The experiment is scheduled to be completed at the Naval Surface Warfare Center in mid-year.

**RADIATION FORCE DUE TO WATER WAVES**

Bruce Denardo, Associate Professor  
Department of Physics  
Sponsor: Naval Sea Systems Command

**OBJECTIVE:** The time-averaged force on a body due to any kind of external wave is referred to as a radiation force, and it occurs because waves carry momentum. When a body emits waves, there is a reaction force opposite to the direction of the wave motion. One purpose of this water wave research is to perform an experiment to ascertain whether the theory of water-wave radiation force is valid. Another purpose is to determine whether the emission of water waves could be a feasible means of propulsion.

**SUMMARY:** The experiment apparatus consists of two rigid plates that are vertically suspended by thread such that they are parallel to and opposite each other. The plates are partially submerged in a dish of liquid that is attached to the top of a vertical shake table. When the shake table is driven with noise in a frequency band, random surface waves are parametrically excited, and the plates move toward each other. The reason for this attraction is that the waves carry momentum, and the wave motion between the plates is negligible. The behavior is analogous to the Casimir effect, in which two conducting, uncharged, parallel plates attract each other due to the zero-point spectrum of electromagnetic radiation. Measurements of the force agree with the water wave theory even at large wave amplitudes, where the theory is expected to break down. The water wave analog applies to side-by-side ships in a rough sea and is distinct from the well-known Bernoulli effect, which occurs when ships are in motion relative to the sea. The water wave force of attraction of two ships can be substantial. Theoretical calculations suggest that water wave propulsion could be practical. A demonstration model boat was built, but the wave propulsion effect was weak due to fundamental problems in the wave generation mechanism.

**PUBLICATION:**


**THESIS DIRECTED:**


**KEYWORDS:** Water Wave Radiation Pressure, Wave Pressure, Radiation Force
THE USE OF BUBBLES FOR PRESSURE MINE SWEEPING
Bruce Denardo, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: When bubbles are introduced into water, there is expected to be a pressure drop in and below the bubble field because the decrease in average density of the bubbly water causes a reduction of hydrostatic pressure. Pressure mines operate by monitoring for a pressure drop that is characteristic of that due to the Bernoulli effect of a passing ship. If such a pressure drop is detected, the mine will detonate. The idea of this research project is to use bubbles to simulate the pressure drop due to a passing ship in order to harmlessly detonate a pressure mine. One issue is the actual nature of the change in pressure due to a bubble field. Because the system is dynamic rather than static, hydrostatic calculations may be substantially inaccurate. The motion of the bubbles will induce an upward flow that is expected to contribute to the lowering of the pressure due to the hydrostatic effect. Calculations of this effect are very difficult and can only be made with many approximations. Experimental investigations must therefore be undertaken.

SUMMARY: As part of Phase I for this research, thesis research student Jeffrey Murawski and the principal investigator (PI) conducted experiments in both the small flow tank and the tow tank at the Naval Postgraduate School. The bubbler consisted of a system of porous tubes connected to a pressurized air source. In the flow tank, the bubbler was held fixed and the pressure was measured at various points in, above, and beyond the bubble field. Pressure drops were detected. Rough scaling arguments suggested that the pressure drop for a much larger apparatus would be sufficient for pressure mine sweeping. As a more realistic test, the tow tank was used; the tow tank is larger and allows the bubbler to be moved through the water (rather than forcing water past the bubbler as in the flow tank). Good results were again obtained. Phase II of the project will involve the testing of different bubbler material and a substantially larger bubbler.

KEYWORDS: Bubbles, Pressure Mine Sweeping

THE DEVELOPMENT OF AN IMAGING TRANSPORT INSTRUMENT FOR MATERIALS – RESEARCH AND EDUCATION
Nancy M. Haegel, Distinguished Professor
Department of Physics
Sponsor: National Science Foundation

OBJECTIVE: To develop an integrated transport system that can perform optical imaging of charge transport phenomena – combining the power of imaging with the need for easy access to local transport parameters. The primary goal is to obtain a resolution of ~100 nm using a near-field optical microscope internal to the scanning electron microscope. The combination of high-resolution transport imaging, standard CL imaging, and spectroscopy and variable temperature capability in one instrument will be unique and will provide opportunities for the study of systems, such as quantum wires, non-uniform electric-field effects, wide bandgap materials, and new materials for solar cell applications. Initial near-field imaging of transport in nanowires has been achieved.

PUBLICATIONS:


PHYSICS

THESES DIRECTED:

Baird, L.


KEYWORDS: Transport Imaging, NSOM, Near Field Optics, Nanoscale Resolution

HIGH Z MATERIALS FOR NUCLEAR RADIATION DETECTION: SYNERGY OF GROWTH, CHARACTERIZATION, AND DEFECT PHYSICS FOR ROOM TEMPERATURE DEVICES

Nancy M. Haegel, Distinguished Professor
Department of Physics
E.E. Haller, et al., University of California-Berkeley
Sponsor: National Science Foundation

OBJECTIVE: To develop new “high Z” materials for room-temperature nuclear-radiation detectors. These detectors must be able to absorb a significant fraction of high-energy radiation, but must also be thin to be able to be manufactured and utilized in large quantity. This collaborative effort with the University of California-Berkeley will investigate new, bi-containing, complex oxide materials for this application. The Naval Postgraduate School contribution is to characterize the transport properties of these new materials.

THESIS DIRECTED:


KEYWORDS: Transport Imaging, Nuclear Radiation Detectors, Complex Oxides

NEXT-GENERATION, REMOTELY TRIGGERED, PLED EMITTERS FOR INDIVIDUAL IDENTIFICATION, FRIEND OR FOE (IFF), FOR SPECIAL FORCES (PART OF THE TECHNOLOGY TRANSITION INITIATIVE)

Nancy M. Haegel, Distinguished Professor
Department of Physics
Sponsor: Special Operations Command, Office of the Secretary of Defense TTI

OBJECTIVE: To produce the next-generation individual identification, friend or foe (IFF), patch for mitigation of shooter-on-shooter fratricide. This work is done in conjunction with Add-Vision, Inc. These devices will be designed to be lighter and brighter than previous generations and will be part of the Technology Transition Initiatives from the Office of the Secretary of Defense in FY09. One-hundred devices will be produced in Spiral 1; field testing and evaluation are planned for summer 2009.

PUBLICATIONS/PRESENTATIONS:

Multiple briefs, including OSD Cross Pollination Workshop, MCCDC (Quantico), Cobra Gold Command Brief, Thai Ministry of Defense, OSD TTI.
THESES DIRECTED:


KEYWORDS: IFF, Polymer Emitting Devices, Fratricide Mitigation

SMART, LIGHTWEIGHT, INFRARED POLYMER EMITTERS FOR INDIVIDUAL (IFF) AND VEHICLE (VMIFF) IDENTIFY, FRIEND OR FOE, AT COBRA GOLD

Nancy M. Haege, Distinguished Professor
Department of Physics

Sponsor: Rapid Transition Technology Office of the Office of the Secretary of Defense

SUMMARY: Novel, lightweight, and low-cost devices for remote identification have been developed using polymer-based light-emitting diodes (PLED). These devices have been field-tested for IIFF applications and found to be effective for shooter-on-shooter IFF to 500+ m. The emission is only visible through night-vision devices and only activates when targeted by friendly forces. A vehicle-mounted version (VMIFF) was also demonstrated, using existing coding on targeting lasers for the Cobra platform and/or the ground laser target designator (GLTD) operated by the forward air controller.

Both the IIFF and the VMIFF technology were demonstrated and tested at Cobra Gold 08. The following goals were accomplished: production of ~4 ruggedized VMIFFs for use in Cobra Gold experimentation; field testing of the new VMIFFs for remote activation from GLTD; design of Cobra Gold test scenarios; and participation at Cobra Gold, with demonstration of activation of VMIFF from Harrier (fixed wing) platforms at a distance of 12+ miles with observation at 16+ miles.

THESES DIRECTED:


KEYWORDS: Vehicle Mounted Identification Friend or Foe, VMIFF, Triggered IFF, Air to Ground Fratricide Mitigation

TRANSPORT IMAGING OF SEMICONDUCTOR NANOWIRES

Nancy M. Haege, Distinguished Professor
Department of Physics
R. Maboudian, University of California-Berkeley

Sponsor: National Science Foundation

OBJECTIVE: To demonstrate direct imaging of charge transport in semiconductor nanowires using a unique method of near-field collection of luminescence associated with carrier recombination. A near-field optical-scanning microscope (NSOM) is operated inside an SEM to collect the distribution of luminescence from point-source generation at the nanometer scale. The initial focus is on transport in SiC films and wires and doped Si nanostructures.
THESES DIRECTED:

Baird, L.


KEYWORDS: Transport Imaging, NSOM, Near Field Optics, Nanoscale Resolution, SiC

AN INVESTIGATION OF NEW KINDS OF ARMOR

Robert S. Hixson, Associate Professor
Department of Physics
Support: RIP

OBJECTIVE: The need for the development of new and advanced armor concepts continues. This includes development of both personnel and vehicle armor. Researchers have begun working to develop new armor concepts using very fundamental shock-compression physics ideas.

SUMMARY: The research team looked at two physical mechanisms to make initial improvements to armor systems. Since the impact of a projectile or fragment onto a material causes shock waves to be generated, the goal is to modify the nature of these waves to minimize the chances of target damage. This was done in two ways. First, researchers evaluated ways to cause the shock wave to spread laterally very quickly as it propagates through the armor material. This was best done by using orthotropic materials; that is, materials that have a much slower wave speed in the through-thickness than laterally. A layered system was developed as the first attempt at calculationally creating such a material. Next, researchers looked at using a porous material to absorb kinetic energy from the shock wave (particle velocity) and turn it into heat material. Very porous materials can do this very efficiently. The first material used was porous aluminum at a relatively small distention. The research team will next look at porous polymers with considerable distention.

THESIS DIRECTED:


KEYWORDS: Shock Compression, Porous, Damage, Armor

ACOUSTIC DETECTION OF ULTRA-HIGH-ENERGY NEUTRINOS

Daphne Kapolka, Senior Lecturer
Department of Physics
Sponsor: Stanford University

OBJECTIVE: To advance the Navy’s ability to detect, classify, identify, and locate low-level transient signals through a collaboration with Stanford on the acoustic detection of neutrinos.

SUMMARY: The interaction of neutrinos with water causes a characteristic short acoustic pulse. The Stanford group, in collaboration with other groups worldwide, has already obtained impressive results detecting neutrinos optically. Stanford has an ongoing project to detect neutrinos using existing hydrophone arrays at the Navy’s Atlantic Undersea Test and Evaluation Center in the Bahamas. Signals collected from this project will be examined to detect neutrino events.
CONFERENCE PUBLICATION:


KEYWORDS: Neutrino, Acoustic, Transient Detection

THE ACOUSTIC SOURCE CHARACTERISTICS OF A SUBMERGED, HIGH-ENERGY LASER PULSE

Daphne Kapolka, Senior Lecturer
Department of Physics
Sponsor: Naval Sea Systems Command-05

OBJECTIVE: To model the acoustic signature of a high-energy laser pulse incident on the sea-water interface to the signature expected from a submerged pulse. The ultimate question for this work is whether pulses from a ship-based FEL could be effectively used as an acoustic source for underwater communications or as an acoustic decoy.

SUMMARY: Experiments were carried out with Ted Jones at the Naval Research Laboratory to investigate the directionality of the acoustic pulse produced by a 100fs 2mJ laser pulse focused just under the surface of water. The range dependence of the pressure amplitude was also examined. The amplitude of the pulse was found to vary with direction; however, this effect is considered likely to be a result of interference between the direct path and the surface reflection. A linear, least-squares fit of the peak pressure amplitude with range revealed a $1/r^{1.2}$ relationship. This is consistent with the expected approximately $1/r$ relationship for pressure amplitudes under 100MPa. The modeling effort employed AUTODYN, a finite element program designed to handle nonlinear processes in explosions. The laser-generated acoustic source was modeled using an explosive of the same volume as the laser spot reported by Vogel for his 10mJ 6ns pulse. The internal energy of the explosive was adjusted until the pressure amplitudes agreed with Vogel’s measured values. The efficiency, pulse length, pulse shape, and variation of pressure amplitude with range achieved with AUTODYN are comparable to those reported by Vogel.

THESIS DIRECTED:


KEYWORDS: Laser Acoustics, Shock Waves, Nonlinear Acoustics, AUTODYN

AUTOMATED DETECTION OF A TARGET OF INTEREST

Daphne Kapolka, Senior Lecturer
Department of Physics
Sponsor: OPNAV N87

OBJECTIVE: To examine a signal of interest to the Office of Naval Intelligence, and to build an automated detection algorithm to alert operators to its presence.

SUMMARY: The signal for this project is classified. However, the automated detector was programmed and tested against detections validated by the ONI’s acoustic analysts to determine the probability-of-detection versus false-alarm rates. Careful consideration was made of the trade-offs in frequency and time-resolution, as well as in the thresholds used.

KEYWORDS: Automated Detection, Passive Sonar, Tonals
PHYSICS

AUTOMATED PASSIVE DETECTION OF PASSING CONTACTS
Daphne Kapolka, Senior Lecturer
Department of Physics
Sponsor: Naval Sea Systems Command-05

OBJECTIVE: To program an automated detection algorithm that can successfully discriminate loud noises displaying a doppler shift and return range and velocity.

SUMMARY: Signals of passing aircraft have been collected. Jet aircraft signatures are broadband with minimal tonal structure, whereas propeller planes exhibit clear doppler shifts on one or more tonals as they pass the closest point of approach (CPA). The automated detection algorithm is based on finding the time where the signal, having exceeded a given threshold, has its peak amplitude. The slope of strongest tonal’s frequency versus time plot at CPA is used as a starting point in the detection algorithm. The cross-correlation between the observed time-frequency plot and a synthetic time-frequency plot will be examined to ascertain whether the presence, velocity, and range of propeller planes can be automatically determined by this method.

KEYWORDS: Automated Detection, Doppler Shift, Passive Acoustics

MODELING THE PERFORMANCE OF MEMS-BASED DIRECTIONAL MICROPHONES
Daphne Kapolka, Senior Lecturer
Department of Physics
Sponsor: Naval Sea Systems Command-05

OBJECTIVE: To increase the physical realism of a finite element model for the micro-electro-mechanical system (MEMS) microphones previously designed, manufactured, and tested by Professor Karunasiri’s group by coupling the acoustic and MEMS modules in COMSOL multiphysics.

SUMMARY: A MEMS-based directional microphone consisting of two plates hinged at the center was modeled using finite element software. A new method was developed in which the sensor was acoustically coupled to an incoming sound wave. The method successfully reproduced results of previous non-acoustic coupled simulations for solid plates. The resonance frequencies matched within 0.8% for the rocking mode and 2% for the bending mode. The displacement amplitudes matched within 17% for the rocking mode and 5% for the bending mode. After ensuring agreement with previous simulations, the model was extended to include more realistic boundary conditions. The sound pressure at the back of the plates was included, along with the drag force on the plates due to the acoustic particle velocity flow. This new model reproduced the experimentally achieved resonance frequency values within 21% for the rocking mode and 2% for the bending mode. The displacement amplitude obtained for the rocking mode was approximately six times lower than the experimental value, while the bending mode amplitude was 47% higher. Manufacturing tolerances for these MEMS devices likely contributed to the discrepancy between simulated and experimental values. A novel design was proposed for increasing the displacement amplitude for both solid and perforated plates through the use of a helmholtz resonator.

THESIS DIRECTED:

KEYWORDS: Simulation, Directional Microphone, COMSOL, MEMS
PHYSICS

A MEMS-BASED MINIATURE MICROPHONE FOR DIRECTIONAL SOUND SENSING
Gamani Karunasiri, Professor
Jose Sinibaldi, Research Associate Professor
Department of Physics
Sponsor: National Science Foundation

OBJECTIVE: To develop an integrated, micro-electro-mechanical system (MEMS)-based, miniature microphone system for a directional sensor.

To develop an integrated, MEMS-based, miniature-microphone system for directional sensing of sound similar to that of the Ormia ochracea fly. The fly employs a unique, coupled mechanical bar system to extract the direction of sound with ears separated only about 500 µm. A set of such sensors can be used for pinpointing explosions by monitoring the direction of sound, which can be deployed using micro air vehicles. In addition, a network of these sensors can be used for unattended movement monitoring.

THESIS DIRECTED:


KEYWORDS: Directional Sound Sensor, Micro-Electro-Mechanical-Systems

REAL-TIME THZ DETECTION USING MICROBOLOMETER FOCAL PLANE ARRAY TECHNOLOGY
Gamani Karunasiri, Professor
Department of Physics
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop a real-time terahertz imaging system using microbolometer focal array technology. The aim of the proposed research is to develop a real-time terahertz imaging system using microbolometer focal array technology originally developed for infrared imaging in the 8-12 µm band. The successful conclusion of the research project will lead to the incorporation of microbolometer technology for real-time imaging at THz frequencies. Such imaging systems can be utilized in stand-off detection of concealed objects and medical imaging with deeper penetration compared to infrared thermography.

THESSES DIRECTED:


KEYWORDS: Terahertz, Microbolometer, Spectroscopy
SUMMARY: Naval Postgraduate School research focuses on innovative solutions to difficult technical problems in the practical employment of rail guns.

- The monolithic rail gun will improve performance, reduce manufacturing costs, and speed military implementation. (LT Forch)
- New projectile designs should reduce rail erosion and improve flight stability. (LT Kearns)
- High-speed tests of rail, interface, and projectile materials and designs to improve bore life. (LT Putnam)
- Power supply development.
- Rail gun barrels are inherently recoilless. (LT Putnam)

The monolithic rail gun is a very promising device for a direct-fire weapon. Its potential in this application exceeds the potential of all other electromagnetic guns currently under investigation. Although the U.S. military does not currently fund this device adequately, there is reason to believe that Russia and China may be doing so. In any case, it would be in the best interests of the U.S. military to provide significantly more support to develop the monolithic rail gun into an operational weapon.

CONFERENCE PUBLICATION:


PRESENTATIONS:

Maier, W., Two posters and one oral presentation, 14th EML Symposium, Victoria Canada, 8-14 June.

Maier, W., One oral presentation and five posters, Department of Defense Innovative Science and Technology ERMG Workshop, Sandia National Laboratories, Albuquerque, New Mexico, 22-25 September.

THESES DIRECTED:


OBJECTIVE: The Naval Postgraduate School (NPS) and Case Western Reserve University began a two-year robotics and systems-development program to address critical topics in the field of autonomous, amphibious vehicles. This work will focus on research in two crucial areas:

Biologically Inspired Robotics for Vehicle Mobility: Autonomous vehicle usage has reached a plateau due to mobility constraints on the current generation of units in the field. This research will lay the foundation for a new generation of autonomous vehicles through the study of crawling locomotion mechanisms occurring in nature. Research performed under this program will leverage past and current work of the principal investigator and colleagues in biologically inspired vehicle design. Specifically, past work in crawling ground vehicles (based on cockroach locomotion) will be expanded to create biologically inspired, mobile, air- and ground-robotic vehicles that will serve as testing and implementation platforms for a very broad array of future-control and field-mobility experiments. Specific focus will be directed towards the removal of shallow water mines in the turbulent surf-zone. Completion of this research will provide a generational leap in mobile robots for amphibious military operations.

Control System Development for Vehicle Autonomy: This research program will focus on the development of autonomous control architectures of sufficient flexibility and breadth such that they may be applied to a very wide range of amphibious vehicles. The goal of this phase of the work is to make progress towards decentralized, flexible, and robust feedback-control systems applicable to force structures of amphibious robots performing all manner of military missions. Specific hardware and software demonstrations are envisioned with applicability to shallow-water surf-zone operations (e.g., mine clearing). Research efforts will focus on hardware and software development autonomous operation in military scenarios. Research results will serve as the basis for a wide range of future testing.

Under this program, past and current work of this research team will be generalized towards the realization of autonomous vehicles capable of performing in both aquatic and terrestrial environments. The synergistic combination of biologically inspired vehicle-design and autonomous control is projected to make a significant impact in the robotics and control systems research community, and will lay a sound foundation for future research efforts leading to self-sustaining, autonomous, amphibious vehicles capable of operating in the turbulent surf-zone.

SUMMARY: The project was funded in December 2008 by the Temasek Defense Systems Institute. To date, the research is organized into two phases for the period of performance. Phase I includes the robot body design and implementation as directed by the Case Western Reserve team. Phase II includes the integration of control and sensors at the Naval Postgraduate School. The project progresses with a preliminary mechanical and control design under review.

CONFERENCE PUBLICATION:


THESIS DIRECTED:

DEPARTMENT OF PHYSICS

2008
Faculty Publications and Presentations
PHYSICS

JOURNALS


CONFERENCE PUBLICATIONS


Karunasiri, G., “MEMS-Based Miniature Directional Sound Sensor,” Electrical Engineering Department Colloquium, University of California at Santa Cruz, 8 May 2008.


**PRESENTATIONS**


Maier, W., DoD Innovative Science and Technology ERMG Workshop, Sandia National Laboratories, Albuquerque, New Mexico, 22-25 September.

Maier, W., 14th EML Symposium, Victoria Canada, 8-14 June (two posters and one oral presentation).


BOOKS


TECHNICAL REPORTS


WHITE PAPERS


Baker, S.R., “Relationship of the Angular Rate Noise Power Spectral Density (PSD) of the Northrop-Grumman LN-200 IMU to Its Angular ‘Random Walk’ Specification; The Angular Rate Noise PSD of the LN-200; The Effect of Aliasing on the LN-200 Angular Rate Noise PSD; Comparison of the LN-200
DEPARTMENT OF SYSTEMS ENGINEERING

DAVID H. OLWELL
CHAIR
OVERVIEW:

Systems engineering focuses on the development of large and complex systems: how do the parts work together in an integrated system given the precise specification of the structure and behavior?

CURRICULA SERVED:

The Naval Postgraduate School (NPS) Department of Systems Engineering (SE) has 27 faculty members with primary appointments, 19 with joint appointments, and 4 administrative staff. We offer Master’s degrees and will soon be offering a doctorate in systems engineering. We have about 60 resident students and about 340 non-resident students. We work closely with the Wayne E. Meyer Institute of Systems Engineering at NPS, especially for student research programs. Our website is http://www.nps.navy.mil/se/.

RESIDENT PROGRAMS OF STUDY:

The Systems Engineering Department supports two resident programs of study:

• Curricula 580, the resident Master of Science in Systems Engineering (MSSE), is a seven-quarter degree program intended for technically oriented military officers, federal government civilians, and qualified international applicants. Students enrolling in the MSSE program may choose from one of three tracks:
  o Combat Systems Engineering
  o Network-Centric Systems Engineering
  o Ship Systems Engineering

• Curricula 308, the resident Master of Science in Systems Engineering and Analysis (MSSEA), is a six-quarter degree program intended primarily for Navy unrestricted line officers.

NON-RESIDENT PROGRAMS OF STUDY:

The Systems Engineering Department also supports three non-resident programs of study:

• Curriculum 311, the Master of Science in Systems Engineering via Distance Learning (MSSE DL), is an eight-quarter, distance-learning degree program intended primarily for federal government civilian scientists and engineers at Navy field activities.

• Curriculum 721, the Master of Science in Systems Engineering Management (MSSEM), is a distance-learning program intended for qualified military officers, senior enlisted, federal government civilians, and defense contractor civilians.

• The Systems Engineering Certificate Program provides the fundamentals of systems engineering to engineering duty officers and other officer communities without requiring the student to enroll in an NPS degree program.

RESEARCH THRUSTS:

Our research seeks to understand: 1) engineering methods and their application to problem solving, and 2) the spectrums of systems engineering – lifecycle, analyses, and integration of systems – balancing resources to ensure timely completion through hands-on research with Navy sponsors. Our mission is to:

• Prepare graduates to ensure national security by providing technical education in designing, building, operating, maintaining, and improving reliable, capable, effective, affordable, complex systems-of-systems that meet the user’s needs when the user needs them.

• Perform research to improve and develop new systems engineering techniques and methods.

• Apply systems engineering techniques and methods to develop cost-effective, timely solutions to urgent national-security problems.
Systems engineering research at NPS can be categorized into four specialization areas: systems engineering methodology, systems engineering applications, system simulation and modeling, and system suitability assessment.

- **Systems engineering methodology** involves the investigation or development of tools and techniques for conceptualizing, designing, and developing systems. Study areas include discovery of fundamental principles of systems theory, elucidating the use of these principles through systems engineering tools and techniques, analyzing the conditions of employing the tools and techniques, and determining the efficacy of those tools and techniques. Specific methodology areas include system requirements generation, requirements allocation, system architecture, system dynamics and control, and risk engineering.

- **Systems engineering applications** involves the application of systems engineering processes to the solution of specific complex problems. This can include conceptual design of systems, investigation of issues associated with integration of system components into system segments, investigation of issues associated with integration of system segments into systems, and the analysis of case studies of successful and/or unsuccessful systems engineering applied to military acquisition programs. Specific application areas include combat systems integration, ship systems engineering, and enterprise systems engineering.

- **System simulation and modeling** involves the development of simulations and models of military systems, evaluation of the efficacy of these simulations and models in providing the information to accomplish systems engineering functions (especially system design requirements and comparison of alternative solutions), and investigation of the characteristics of simulations and models that lead to outputs that are useful in the systems engineering process.

- **System suitability assessment** involves the study of tools, techniques, and disciplines that permit the assessment of the suitability of systems in meeting requirements. Requirements can include performance, availability, operability, and cost. Specific suitability assessment areas include reliability engineering, system survivability, and system cost estimation and control.

### RESEARCH PROGRAM (Research and Academic)-FY2008:

The Department of Systems Engineering delivered $1.3M in reimbursable education, $0.4M in reimbursable research, and about $0.3M in other externally funded activities.

Funded research included work by Department Chair David Olwell in modeling and simulation education for lifelong learning in the acquisition workforce; Associate Professor Clifford Whitcomb in system-of-systems architecture for unmanned vehicle Sentry development; Associate Professor Ed Kujawski in soldier network enabled operations test and evaluation methodology; Lecturer Greg Miller in system engineering plan reviews for Joint Counter Radio-Controlled IED Electronic Warfare System and Global Command and Control System-Maritime; Lecturer Gary Langford in peer-produced virtual environments for system development; Assistant Professor Rachel Goshorn in smart sensor fusion, prediction, and classification in maritime domain awareness net-centric enterprise systems; and Assistant Professor Ravi Vaidyanathan in robotics.

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Systems Engineering is provided below:
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SMART SENSOR FUSION, PREDICTION, AND CLASSIFICATION IN THE MARITIME
DOMAIN AWARENESS, NET-CENTRIC, ENTERPRISE-SYSTEMS PROGRAM
Rachel Goshorn, Assistant Professor
Department of Systems Engineering
Sponsor: Naval Postgraduate School

SUMMARY: The goal of this research is to develop smart sensor fusion, prediction, and classification in the maritime domain awareness (MDA), net-centric, enterprise-systems program. The system (the needs and objectives for education) was modeled, and needs were discovered through numerous meetings with research sponsors. The model was tested on experts through another 15-20 meetings, with very positive feedback on the model and concepts (including suggestions for updates, iterations, etc.). Technical research in smart sensor fusion, prediction, and classification was carried out with net-centric enterprise systems. Areas of research that were advanced include ambient assisted living through smart hand-gesture behavior analysis and computer vision; abnormal behavior detection through smart camera/cluster-based architectures in a net-centric system; a generalized approach to artificial intelligence (AI) behavior modeling as Detection, Identification, Prediction, and Reaction (DIPR) in AI Systems Solutions; and advanced AI behavior analysis and sensor fusion. A smart sensor network with smart sensor fusion and classification and prediction was developed in the Network-Centric Systems-Engineering Lab. A course on Artificial Intelligence Systems Engineering was developed and taught. This course was used to assemble the networks and software through course projects.

SYSTEMS ENGINEERING STUDIES FOR STRATEGIC SYSTEMS PROGRAMS
Robert Harney, Associate Professor
Department of Systems Engineering
Sponsor: Department of the Navy Strategic Programs

OBJECTIVE: To facilitate student interest and research in areas of relevance to strategic systems.

SUMMARY: This project provided resource materials for approximately a dozen systems engineering students. It provided those students with multiple opportunities to travel to conferences and visit program offices.

KEYWORDS: Systems Engineering, Strategic Systems

CSS SOLDIER NETWORK-ENABLED OPERATIONS CBA AND JOINT
TEST AND EVALUATION METHODOLOGY
Edouard Kujawski, Associate Professor
Department of Systems Engineering
Sponsor: TRADOC Analysis Center-Monterey

SUMMARY: This study focused on Combat Service Support soldiers in and around command posts, built-up areas, and fixed operating bases (FOBs). This group supported a capabilities-based assessment to determine if capability gaps exist, and if so, what possible solutions might fill these capability gaps. The research team contributed the following to the functional needs analysis and the functional solutions analysis: a) the risk assessment, b) development and application of multi-attribute decision-support tools, and c) synthesis of results.
SUMMARY: This study focused on the joint test and evaluation methodology. The research team contributed to the development of a JTEM measure framework for test-factor screening purposes and for drawing insights and making recommendations based upon test data. This work contributed to evaluating the joint mission effectiveness (JMe) of a system of systems in a joint mission environment. The Matrix of Failure Mode Effects Analysis (MFMEA) was proposed as a systematic, inductive approach to map the relationships between basic failures at a low level and their impacts at the higher levels. This research also showed how test analysts can use Department of Defense architecture framework products to support JMe evaluation strategy development.

OBJECTIVE: Peer production (PP) is an appropriate means to design and develop Department of Defense systems. Currently, PP only exists on the fringe. It is applied to projects involving the exchange of information, but has not been used as a broad methodology for systems design and development. The principles for broad application of PP can be discerned through in-depth analysis of current peer-produced projects and the technologies that make PP feasible. Two components are necessary to adequately assess the applicability of PP. First, the process of PP must be defined and formalized so that PP can be applied appropriately to develop systems according to requirements. Second, the axioms of PP must be tested through experimentation. This experiment will involve application of the proposed principles to develop a prototype system according to requirements.

OBJECTIVE: To formulate a framework to facilitate applied research that is expected to result in very cost-effective and practical recommendations that address and resolve some outstanding issues related to the disruption of commerce in the Straits of Malacca; and to promote academic discussion to improve the theoretical and programmatic foundations of intelligence analyses using open-source data.

SUMMARY: Based on current systems engineering best-practice in Department of Defense acquisition and current Navy and joint instructions, the Naval Postgraduate School team analyzed the existing draft SEP and provided a report detailing its weaknesses and recommending improvements. Areas examined included the SEP’s connection with the program’s acquisition plan and supporting documents and correct tailoring of the SE process itself, including meeting specific requirements for an MS C decision. This effort
included meeting with the GCCS-M engineering team in San Diego, California. Recommended changes were incorporated into the document.

SYSTEMS ENGINEERING PLAN REVIEW FOR THE JCREW PROGRAM
Greg Miller, Lecturer
Department of Systems Engineering
Sponsor: Naval Explosive Ordnance Disposal Technology Division

SUMMARY: Based on current systems engineering best-practice in Department of Defense acquisition and current Navy and joint instructions, the Naval Postgraduate School (NPS) team analyzed the existing SEP and provided a report detailing its weaknesses and recommending improvements. Areas examined included the SEP’s connection with the program’s acquisition plan and supporting documents and correct tailoring of the SE process itself. This effort included meeting with the JCREW engineering team at the Naval Explosive Ordnance Disposal Technology Division at Indian Head, Maryland. Recommended changes were incorporated into the document.

EDUCATING THE ACQUISITION AND TEST WORKFORCE: WORKFORCE MODELING AND SIMULATION EDUCATION AND TRAINING FOR LIFELONG LEARNING
David H. Olwell, Professor
Department of Systems Engineering
Sponsor: Defense Modeling and Simulation Office

SUMMARY: Modeling and simulation (M&S) is an essential capability for managing risk and reducing time and cost for acquisition. There is currently no unified approach for determining which M&S tools to use, when to use them, and how to use them across the development lifecycle. Additionally, a range of training options is needed to improve the multi-service community members’ capabilities to select and use M&S tools effectively and efficiently. These include initial education and training, refresher training, continuing education, and certification opportunities.

AN EVALUATION OF ENERGY CONSUMPTION AND ENERGY EFFICIENCY IN THE NAVY
David H. Olwell, Professor
Department of Systems Engineering
Sponsor: Office of Naval Research

SUMMARY: Funds are provided to devise a systems-approach-based plan for the future development of a model-based methodology to evaluate energy consumption and identify technology insertion opportunities and infrastructure modifications to improve energy efficiency in a variety of Navy applications, afloat and ashore.
FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS
Ravi Vaidyanathan, Assistant Professor
Department of Systems Engineering
Sponsor: U.S. Special Operations Command

SUMMARY: Not available.

TRAVEL SUPPORT FOR PLENARY SPEAKERS FOR THE 2008
ADAPTIVE MOVEMENT OF ANIMALS AND MACHINES (AMAM)
INTERNATIONAL CONFERENCE
Ravi Vaidyanathan, Assistant Professor
Department of Systems Engineering
Sponsor: Office of Naval Research Global

OBJECTIVE: The program will provide travel support for international speakers to present plenary lectures at the Fourth International Symposium on Adaptive Movement of Animals and Machines (AMAM 2008), which will take place from 1-6 June 2008 in Cleveland, Ohio. This will be the first time this event is hosted in the U.S. The support will bring world-renowned academics, whose work has specifically set new paradigms in mobile robotics, to research circles in the U.S. Although unmanned and robotic vehicles are rapidly assuming a significant role in U.S. military operations, the vast majority of existing systems remain limited in their utility in the field. The Naval Postgraduate School as an institution has invested significant effort and resources into overcoming this capability gap. AMAM will bring together top researchers around the globe to provide a forum exclusively to address issues of adaptability and performance within the context of a range of operational conditions. The vision is to bring together scientists and engineers to advance the knowledge of adaptation and investigate system behavior.

THE ARCHITECTURE DEVELOPMENT PROCESS FOR THE UNMANNED VEHICLE
SENTRY (UV SENTRY) SYSTEMS-OF-SYSTEMS
Clifford Whitcomb, Associate Professor
Department of Systems Engineering
Sponsor: Office of Naval Research

SYSTEM-OF-SYSTEMS ARCHITECTURE DEVELOPMENT FOR THE
UNMANNED VEHICLE SENTRY (UV SENTRY) PROGRAM
Clifford Whitcomb, Associate Professor
Department of Systems Engineering
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To investigate a methodology for conducting systems and systems-of-systems architecting studies in the context of the Office of Naval Research Unmanned Vehicle Sentry Program.

A SYSTEM-OF-SYSTEMS ARCHITECTURE FEASIBILITY STUDY FOR THE
UNMANNED VEHICLE (UV) SENTRY PROGRAM
Clifford Whitcomb, Associate Professor
Department of Systems Engineering
Sponsor: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: To conduct a feasibility study for a system-of-systems architecture for the unmanned vehicle (UV) Sentry based on previous program-related project outcomes and references, such as the NSWC, Carderock Innovation Center UV Sentry Project, the DODAF, 000 and DoN SOS Engineering Guide, 000 Mission Engineering Plan, UV Sentry Program documents to date, and fundamental system architecting principles.
JOURNAL PAPERS/ARTICLES


CONFERENCE PUBLICATIONS


PRESENTATIONS


Goshorn, R. and Goshorn, D., “Vision-Based Syntactical Classification of Hand Gestures to Enable Robust Human Computer Interaction,” Special Session on Vision Based Reasoning, Third Workshop on Artificial Intelligence Technologies for Ambient Intelligence, collocated with the 18th European Conference on Artificial Intelligence, Patras, Greece.


Kujawski, E., “Where Have All the Reliability Requirements Gone?” Conference on Systems Engineering Research, Los Angeles, California, 4-5 April 2008.


TECHNICAL REPORTS


SPACE SYSTEMS
ACADEMIC GROUP

RUDOLF PANHOLZER
CHAIR
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, the SSAG 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 lifecycle, 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 the Naval Postgraduate School. 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 and Astronautical 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 Exploitation of National Capabilities (TENCAP) Space Chair
- Space-Systems Academic Chair
- NASA Michael J. Smith Space-Systems Chair
- National Reconnaissance Office Chair
- MASINT 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 and 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)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include 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: $1.3M
<table>
<thead>
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DESIGN AND QUALIFICATION TESTING OF THE NAVAL POSTGRADUATE SCHOOL CUBESAT LAUNCHER

James H. Newman, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: To investigate a method to substantially increase the number of CubeSat launch opportunities for U.S. government, industry, and academic CubeSat developers on U.S. launches. Although originally developed as a satellite standard in the U.S., most CubeSats are launched overseas due to the difficulty in getting secondary payloads onto domestic launches. This project takes the development of a CubeSat Launcher from the model stage through the design, construction, and test of a flight-qualified unit.

SUMMARY: This project continued the Phase I work sponsored by the California Space Education and Workforce Institute to produce a one-half scale model of a CubeSat Launcher, or NPSCuL (pronounced NPS “cool”). The NPSCuL model was successfully built using an educational paradigm whereby the student working on the project became the project program manager. This student had responsibility for the budget, schedule, and deliverables for the project, under the guidance of the principal investigator. Based on his success and graduation in September 2008, three students have signed up to take the prototype to a flight unit, using the same concept of a student program manager in charge of the overall project, including budget and schedule, and the whole team dividing up responsibility for the deliverables. The sponsor has identified a potential flight opportunity in late 2010 on a domestic launch for NPSCuL, and the prospect of a launch in the near future adds realism and urgency to the project. Progress to date has included the development of the mass models needed for testing and the basic structural design required for the structure. In addition to a resource budget, a mass budget was determined and schedules were developed to support completion of the project on time and on budget, with an appropriate margin.

PRESENTATIONS:


THESIS DIRECTED:

OTHER:

This project was successfully presented to the Department of the Navy and the Department of Defense Space Experiment Review Board for consideration for a launch opportunity. The NPSCuL Project has been ranked for an eventual launch opportunity.

KEYWORDS: CubeSat, Launcher, Pico-Satellite, Domestic Launch

PHASE II: FLIGHT-BUILD OF A NANO-SATELLITE ADVANCED-
SOLAR-CELL TESTER

James H. Newman, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: To investigate the use of very small satellites to accomplish focused research of national interest. To support this objective, this project will produce the Naval Postgraduate School’s (NPS) first satellite using the CubeSat form factor, thereby gaining experience in all phases of CubeSat systems integration, payload development, and flight operations. The use of the CubeSat form factor is expected to enhance our capability to perform certain research of national interest that is also accessible and interesting to the NPS student body. The first CubeSat characterizes the performance of various solar cells in the space environment. The results are of general interest and demonstrate the capability of the CubeSat as a technology demonstration satellite, as well as a potential platform for more sophisticated experiments.

SUMMARY: The NPS Solar Cell Array Tester (NPS-SCAT) prototype was successfully built using a model for thesis work whereby the student working on the project became the project program manager. This student had responsibility for project budget, schedule, and deliverables, under the guidance of the principal investigator. Based on his success and graduation in September 2008, four students have signed up to take the prototype to a flight unit, using the same concept of a student program manager in charge of budget and schedule, and the whole team dividing up the deliverables. After a successful presentation to the Space Experiments Review Board, the Space Test Program has offered the possibility of a launch on the space shuttle in late 2010, adding realism to the project. The project’s progress to date has included verifying the needed flight systems required to be integrated and procurement of the required systems, including command and data handling, communications, and power. The payload subsystem was designed and readied for test. Mass and power budgets were determined and budgets and schedules were developed to support completion of the project on time and on budget, with an appropriate margin. Development of concepts for satellite operations was initiated.

CONFERENCE PRESENTATION:


THESIS DIRECTED:


OTHER:

This project was successfully presented to the Department of the Navy and the Department of Defense Space Experiment Review Board for consideration for a launch opportunity.

KEYWORDS: CubeSat, Solar Cell, Pico-Satellite
A CASE STUDY OF A NATIONAL SECURITY SPACE PROGRAM
Rudy Panholzer, Professor and Chair
Space Systems Academic Group
Sponsor: Secretary of the Air Force/FMBMB-AFOY

OBJECTIVE: A case study of a national security program is proposed. Case studies facilitate learning by emphasizing the long-term consequences of the systems engineering/programmatic decisions on the cost, schedule, and operational effectiveness of major programs. The proposed research will support the thesis research of several students, and the resultant report will be used to supplement learning in the space-systems curricula.

DESIGN AND PROTOTYPE-BUILD OF A NANO-SATELLITE
ADVANCED-SOLAR-CELL TESTER
Rudy Panholzer, Professor and Chair
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: To design and prototype a solar cell tester using a CubeSat platform. The CubeSat-class satellite is a standard that is seeing growing acceptance in research institutes due to its small size and relatively low cost. These very small satellites (stackable ten-centimeter cubes, one kilogram each) can provide Naval Postgraduate School researchers and students with exciting, relatively short turnaround research projects in research payloads and satellite engineering and operations.

NAVAL SPACE SYSTEMS ACADEMIC CHAIR
Rudy Panholzer, Professor and Chair
Space Systems Academic Group
Sponsor: Naval Network Warfare Command

OBJECTIVE: The Naval Space Systems Academic Chair will engage in instruction and research and act as a consultant in the area of specialization to students and faculty of the Naval Postgraduate School.

SPACE-SYSTEMS ENGINEERING EXPERIENCE TOUR AND SPACE-SYSTEMS ENGINEERING SUPPORT
Rudy Panholzer, Professor and Chair
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: To fund the Space Systems Academic Group, Space-Systems Engineering, space cadre support, and space-systems engineering student experience tours.

SPACE-SYSTEMS OPERATIONS STUDENT THESIS/EXPERIENCE TOUR
Rudy Panholzer, Professor and Chair
Space Systems Academic Group
Sponsor: Naval Network Warfare Command

OBJECTIVE: To fund the Space Systems Academic Group (SSAG), Space-Systems Operations, student thesis research-related travel and experience-tour travel.
STUDENT RIDESHARE PAYLOAD MODEL
Rudy Panholzer, Professor and Chair
Space Systems Academic Group
Sponsor: California Space Education Workforce Institute

SUMMARY: The Naval Postgraduate School has robust space-systems engineering and operations research and education programs. The operations education/research focuses on design, development, and acquisition management of space communications, navigation, surveillance, electronic warfare, and environmental sensing systems.

TECHNOLOGY REVIEW AND UPDATE (TRAU) FOR TECHNICAL PERSONNEL (CHECKS)
Rudy Panholzer, Professor and Chair
Space Systems Academic Group
Sponsor: Various

SUMMARY: Technology Review and Update is a short-course designed for military, government, and civilian technical personnel and decision-makers interested in refreshing and updating their knowledge in important technical areas.
CONFERENCE PRESENTATIONS


GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

ROBERT N. BECK
DEAN
OVERVIEW:

The mission of the Graduate School of Business and Public Policy is to serve the nation by educating military officers and Department of Defense civilians in defense-focused business and public policy by conducting scholarly research in defense management and public policy and providing intellectual resources for leaders and organizations concerned with national-defense management practice and policies.

- **In Education:** Through graduate and non-degree programs, to develop students’ abilities to analyze, think critically, and take intelligent action so they can more effectively carry out their future professional responsibilities to manage organizations, resources, people, and programs in complex and sometimes life-threatening environments.
- **In Research:** To conduct scholarly, technical, and applied research that supports military decision-making, problem solving, and policy setting; improves management processes and organizational effectiveness; contributes knowledge to academic disciplines; and advances graduate education.
- **In Professional Service:** To provide professional expertise that advances knowledge and business management within the Naval Postgraduate School (NPS), the Department of the Navy, the Department of Defense, and other government agencies, as well as in 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 incorporated in classroom instruction. The school’s research program goals are specified as follows on the Graduate School of Business and Public Policy webpage: [http://www.nps.navy.mil/gsbpp/research.htm](http://www.nps.navy.mil/gsbpp/research.htm).

- Increase the quality and quantity of relevant defense-oriented research.
- Catalyze a broad and robust research program.
- Involve top researchers, practitioners, and graduate students in defense-oriented research useful to DoD policy/decision-making processes.
- Augment and complement cooperative, interdisciplinary research activities.
- Disseminate relevant, important results to researchers, sponsors, policy-makers, and practitioners.
- Integrate defense-oriented research with education, DoD workforce training, and standardized policy practices.
- Establish and maintain a community of academic and professional scholars engaged in exploratory and applied research to address complicated defense issues from a number of perspectives, while integrating defense applications into familiar business disciplines.

CURRICULA SERVED:

The Graduate School of Business and Public Policy has primary responsibility for seven graduate degrees. The largest degree program is a group of curricula in the defense-focused Master of Business Administration, with the following curricular concentration areas:

- Acquisition Management
- Logistics Management
- Financial Management
- Information Management
Another resident program is the Master of Science in Management, with a concentration in Manpower Analysis. A third resident degree, the Master of Executive Management (MEM), started in July 2006.

Distance learning graduate programs offered by the Graduate School of Business and Public Policy include: an Executive Master of Business Administration degree program (targeting senior Navy lieutenants through commanders, particularly from the unrestricted line communities, who have middle-management level experience); 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 the 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 Graduate School of Business and Public Policy also offers two certificate programs: the Practical Comptrollership course, sponsored by the Assistant Secretary of the Navy (Financial Management and Comptroller), targets individuals (civilian and military) occupying or reporting financial management positions; and the Advanced Acquisition program, which provides a Level III Education Certificate in Program Management for the Department of Defense acquisition workforce.

The school’s graduate programs achieved the distinction of being one of only two graduate management programs in the country earning dual accreditation by the Association to Advance Collegiate Schools of Business (AACSB) and the National Association of Schools of Public Affairs and Administration (NASPAA).

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 the 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

RESEARCH THRUSTS:

Research in the Graduate School of Business and Public Policy is multidisciplinary and often widely diverse, but this research is directed toward a common set of goals. As stated in the school’s mission statement, the faculty conducts a variety of research to:

- Support military decision-making, problem-solving, and policy-setting
- Improve administrative processes and organizational effectiveness
- Contribute knowledge to academic disciplines
- Advance the mission of graduate education

The primary goal of the school’s research program is to provide the Navy and the DoD with the capability of managing defense systems efficiently and effectively. This includes the efficient and effective utilization of resources, which derive from an existing base of knowledge or may require the development of new concepts and theory. Thus, the school recognizes the importance of both basic and applied research to the Navy and the DoD, and it seeks to balance both types of research.

Concepts, theory, and existing knowledge can generally be identified with a particular functional area or discipline. Actual defense policy and management decisions or policies often require information or perspectives drawn from a variety of functional areas and professional expertise. Consequently, in addition to pursuing functional area research with a critical mass of faculty, the school actively seeks to engage in
cooperative, interdisciplinary research. Such research 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 and professional experience can share information and findings in a unified and truly systematic fashion.

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 theory for practice.

Beginning in 2002, the Graduate School of Business and Public Policy initiated an Acquisition Research Program to provide leadership in innovation and creative problem-solving and an on-going dialogue to support the evolution of Department of Defense acquisition strategies. The program goals include:

- Establishing NPS acquisition research as an integral part of policy-making for Departments of Defense and Navy officials.
- Creating a stream of relevant information concerning the performance of DoD acquisition policies with viable recommendations for continuous process improvement.
- Preparing the workforce to participate in the continued evolution of the defense acquisition process.
- Collaborating with other universities, think tanks, industry, and government in acquisition research.

Supported primarily by the Graduate School of Business and Public Policy Acquisition Chair, currently held by Rear Admiral Jim Greene, USN, (Ret.), this research program initiated 15 research projects in 2003, with the number increasing to well over 20 in 2004, and over 35 in 2005. These projects include several collaborative efforts with Dr. Jacques Gansler (former Under Secretary of Defense for Acquisition, Technology, and Logistics) and other faculty members at the University of Maryland. Primary research sponsors include: Assistant Secretary of the Navy (Research, Development, and Acquisition), Naval Sea Systems Command, Program Executive Office (Ships), Program Executive Office (Integrated Warfare Systems), and the Defense Contract Management Agency (International).

A significant portion of this research funding is open-ended, restricted only to research topics involving acquisition issues broadly defined. The Graduate School of Business and Public Policy has established a competitive, internal proposal process to allocate these funds; the call for proposals is distributed to faculty from across the Naval Postgraduate School. Priority is given to proposals that involve collaboration between tenure-track and non-tenure-track faculty members and to proposals involving thesis students and MBA project teams. The objective is to encourage collaboration that exploits the school’s academic and professional expertise, a collaboration that provides the Graduate School of Business and Public Policy with a strong comparative advantage for defense acquisition policy research. This program has been growing rapidly, with four of five proposals funded in AY2004, nine of eleven proposals funded in AY2005, and 27 proposals submitted for AY2007.

The Acquisition Research Program also hosts an annual Acquisition Research Symposium in Monterey, California. The third symposium, in May 2006, involved well over 100 people, including researchers and acquisition policy- and decision-makers from across the United States. The Honorable Kenneth J. Krieg, Under Secretary of Defense (Acquisition, Technology, and Logistics), delivered the keynote address. Symposium details are available on the symposium website: [http://www.researchsymposium.org/ocs/](http://www.researchsymposium.org/ocs/).
This research represents seminal scholarly work in the area of defense acquisition and draws on expertise in accounting, contracting, economics, information systems, law, organizational design, public policy, and other academic disciplines. A complete description of the Acquisition Research Program, including funded projects and supporting faculty, is available on the acquisition research website: http://www.nps.navy.mil/gsbpp/ACQN/index.htm.

Professor Keith Snider, Senior Lecturers Mike Boudreau, John Dillard, Marshall Engelbeck, Raymond Franck, and Dave Matthews, and Lecturers Jeff Cuskey, Brad Naegle, Rene Rendon, and Don Summers are involved in this research area. The Acquisition Research Program also draws on faculty from all of the other discipline areas.

**Logistics and Transportation:** The primary mission of the logistics and transportation group is to educate military officers and DoD civilians in state-of-the-art concepts of logistics, transportation, and supply-chain 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 and management effectiveness. Major research areas include:

- DoD inventory policy
- Cross-docking, inventory management, and cycle-time reduction
- Defense transportation and distribution systems
- Total asset visibility and real-time logistics
- Metrics and performance-based logistics
- Spiral development
- Modeling and simulation for logistics decision support
- Supply-chain management and lean manufacturing
- Sea-based logistics for the Navy and the Marine Corps

Much of this work has been supported through the Acquisition Research Program and its associated sponsors. Additional sponsors include the Office of Naval Research, NAVAIR, the Military Sealift Command, the U.S. Transportation Command, and the Naval Surface Warfare Center.

Professors Aruna Apte, Uday M. Apte, Kenneth Doerr, Geraldo Ferrer, Keebom Kang, Ira Lewis, and Senior Lecturer Don Eaton are involved in this research area.

**Financial Management:** Research in the area of financial management has become increasingly important since the end of the Cold War and the events of 9-11. The financial-management (FM) group has identified three major functional areas as targets of opportunity for future research. These are:

- Financial resource policy formulation, analysis, and management
- Financial management and budgeting
- Organizational efficiency, managerial control, and performance metrics

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, and execution system; and relationships between financial management, contracting, acquisition, and other policy fields. Financial management and budgeting includes: federal, DoD, and Navy budget formulation and execution; impacts of budget allocation, reallocation, and reduction; implementation of Defense Resource Management Systems; and the Chief Financial Officer Act and federal financial management reforms. The research area of organizational efficiency, managerial control, and performance metrics, in turn, covers: mapping goals and objectives to a defense organization’s strategic themes using a balanced scorecard, examining the efficiency of defense sector consolidation, and the cost effectiveness of lease versus buy programs.

Sponsors for this research include: the Assistant Secretary of the Navy (Research, Development, and Acquisition), Program Executive Office (Ships); the Program Executive Office (Integrated Warfare Systems); the Office of the Comptroller, COMNAVAIRPAC (CNAP); the U.S. Department of Justice; and the Personnel Security Research Center (Department of Defense).
Professors Richard Doyle, Kenneth J. Euske, Nayantara Hensel, Lawrence Jones, Jerry McCaffery, Joe San Miguel, Nicole Thibodeau, Carmelita Troy, Senior Lecturer John Mutty, Commander Phil Candreva, USN, and Colonel Randy Howard, USAF, are involved in this research area.

**Manpower Systems Analysis:** As noted above, the primary goal of the department’s research programs is to provide defense policy-makers with the capability of utilizing resources with maximum efficiency and effectiveness. This includes human resources, the focus of research in the manpower systems analysis (MSA) group. Defense manpower policy-makers have been faced with many challenges since the end of the Cold War and the events of 9-11. Key among these challenges is an over 30 percent reduction of the active-duty force; budget reductions in recruiting and advertising; a steady, high operational tempo and deployment schedule with fewer people, new missions, and increasing pressure to change the “culture” of military service; renewed efforts toward population representation of women and racial/ethnic minorities throughout the force; a 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 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
- Innovations in instructional technologies
- Innovations in enlisted assignments and auctions for assignment incentive pay
- Personnel retention in critical fields, including auction-based approaches
- Reduction of first-term attrition rates among enlisted personnel
- Force management programs and planning
- Force structure and cost analysis
- Auction-based approaches to force shaping
- Career-force modeling
- Officer promotion and performance
- Civil-military relations and the all-volunteer force
- Manpower management in Reserve components

Sponsors for this research include: the Office of the Chief of Naval Operations (N-1, N-1H, N-1Z, N-12, N-13, and N-14), Navy Personnel Research, Studies and Technology, and the Office of the Assistant Secretary of Defense.

Professors Pete Coughlan, Mark Eitelberg, William Gates, Stephen Mehay, Elda Pema, Yu-Chu Shen, Senior Lecturer Alice Crawford, and Lecturer Bill Hatch are involved in this research area.

**Organization, Management, and Policy Analysis:** Faculty members in this functional area pursue basic and applied research on key management issues at a variety of organizational levels. Faculty members bring a strategic perspective to this work, seeking to identify courses of action that will best achieve organizational goals in a given setting. Individual faculty members are acknowledged experts who publish leading-edge research on a variety of issues. Top management issues include strategy and entrepreneurship, appreciative inquiry and positive change, organizational design (including the use of self-managing groups), social network analysis, ethics, collaboration in teams, managerial communications, and the development of culture.

There is a strong expertise in leadership at all organizational levels. Leadership issues studied by faculty include leadership development, the identification of key leadership skills, innovation and change, motivational strategies, empowerment, coaching, communications strategies, conflict management, and constructive uses of power. Faculty members are also experts in a variety of research methodologies—from highly sophisticated quantitative to in-depth qualitative analyses.
In addition to their subject area and methodological expertise, faculty members have developed considerable knowledge of current military organizations through their research. Most of this work has been with Navy organizations, such as the NAVSUP, NAVAIR, CNET, NETWARCOM, Naval Reserves, and CINCLANTFLEET. However, faculty members have also worked with organizations in other service branches, including extensive work with the U.S. Army Reserve Command and Coast Guard Headquarters. Recent DoD-wide research includes work for the Office of Force Transformation. Individual faculty members have also conducted research for other U.S. government agencies, including the Office of Personnel Management, the Department of Homeland Security, and the Center for Disease Control. Faculty members have also consulted with state government agencies, the United Nations, and private-sector organizations. Supervising student theses has broadened this knowledge even more. This organizational expertise increases the value of faculty as applied researchers for DoN and DoD organizations.

Professors Frank Barrett, Doug Brook, Nick Dew, Deborah Gibbons, Susan Hocevar, Cindy King, Leslie Sekerka, Jim Suchan, Gail Fann Thomas, and Roxanne Zolin are involved in this research.

RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. 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:

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ORGANIZATIONAL HEALING: ENABlers IN CRISIS AND TRAUMA
Edward H. Powley, Assistant Professor of Management
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School

SUMMARY: This research examined physical healing as a metaphor for healing the organizational fabric. Using an in-depth case study of a shooting and hostage incident, this paper provides a more nuanced view of individual actions and reactions that encourage healing. Healing is different from coping; it is more akin to mending and tending to relationships, people, and organizational dynamics. The principal investigator (PI) will prepare a paper on healing and organizations: what is it, how does it operate, what are its philosophical roots, what has been said about it, and what it looks like as a theoretical construct. As a continuation of this work, the PI will describe its usefulness in various settings and draw from healthcare, nursing, and emergency management perspectives to develop the concept. Work on organizational healing is ongoing.

PUBLICATIONS:


PRESENTATION:

POSITIVE ORGANIZATIONAL CHANGE
Edward H. Powley, Assistant Professor of Management
Graduate School of Business and Public Policy
Sponsor: Research Initiation Program

SUMMARY: Completed a co-edited special journal issue on positive organizational change with Dr. Kim S. Cameron (University of Michigan) for the Journal of Applied Behavioral Science (JABS).

From the call for papers: “Positive organizational change refers to changes that lead to developing human strength, producing resilience and restoration, fostering vitality, reaching positively deviant performance, and cultivating extraordinary individuals and organizations. The term positive may have at least three different connotations: a) positive deviance, extraordinary success, or spectacularly effective organizational performance; b) an affirmative bias toward positive communication, positive rewards, positive behaviors, positive strengths, or other positive practices in organizational behavior; and c) virtuousness, the best of the human condition, or positive principles that are often labeled as examples of fundamental goodness.”


PRESENTATIONS:


THESES DIRECTED:


RESILIENCE ACTIVATION IN THE CRITICAL PERIOD OF CRISIS
Edward H. Powley, Assistant Professor of Management
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School

OBJECTIVE: To examine three social mechanisms that explain how resilience, the latent capacity for adjusting positively in adversity, is activated during the critical period of crisis.

SUMMARY: Using an in-depth case study of a shooting and hostage incident, the principal investigator explained how the suspension of organization is a primary mechanism that undoes routines, procedures, and social structure, which then enables compassionate witnessing and relational redundancy, two social mechanisms that activate organizational resilience. The work for this paper was completed previously, and a paper was submitted for publication in November 2007.

PUBLICATION:


TRUST AND MISTRUST IN ORGANIZATIONS
Edward H. Powley, Assistant Professor of Management
Graduate School of Business and Public Policy
Mark E. Nissen, Professor and OASD-NII Research Chair Professor of Command and Control
Department of Information Sciences
Sponsor: Defense Advanced Research Projects Agency

SUMMARY: This research examined the role and manifestation of trust in varying organizational design contingencies.

Trust matters for task performance, particularly when the task involves dealing with a potential threat or crisis. When faced with important decisions in such situations, the social connections between managers and front-line employees are critical. This research drew on the concept of trust (Mayer, Davis, and
Schoorman, 1995) and organizational design (Mintzberg, 1979). Based on results from a computer simulation module (ELICIT), a study was presented that examined the effects of various trust conditions and social configurations. It was found that collaborative, sharing practices (an organic, flat environment) in a trusting organizational climate produce the greatest levels of task performance. When decisions need to be expedited, however, trust is non-significant and formal relationships between organization members are more salient.

PRESENTATION:


THESIS DIRECTED:

GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

2008
Faculty Publications and Presentations
PUBLICATIONS


PRESENTATION


INSTITUTES AND CENTERS

CEBROWSKI INSTITUTE
FOR INFORMATION INNOVATION
AND SUPERIORITY

WAYNE E. MEYER INSTITUTE
OF SYSTEMS ENGINEERING

MOVES INSTITUTE
(MODELING, VIRTUAL ENVIRONMENTS
AND SIMULATION)

CENTER FOR INTERDISCIPLINARY
REMTELY PILOTED AIRCRAFT STUDIES

CENTER FOR DEFENSE TECHNOLOGY
AND EDUCATION FOR THE
MILITARY SERVICES

NATIONAL SECURITY INSTITUTE

CENTER FOR ASYMMETRIC WARFARE

CENTER FOR CONTEMPORARY CONFLICT
CEBROWSKI INSTITUTE
FOR INFORMATION INNOVATION AND SUPERIORITY

PETER J. DENNING
DIRECTOR
CEBROWSKI INSTITUTE

OVERVIEW:

The Cebrowski Institute for Innovation and Information Superiority sponsors cross-discipline investigations into ways that information processes and technologies, organizational development, and personal skills can strengthen stability, transition operations, crisis response, warfighting, and defense in support of national and global security.

Areas of focus include hastily formed networks, indicators of impending crisis, globalization, architectures for network-centric operations, World Wide Consortium for the Grid (W2COG), maritime domain awareness, mobile devices and communications, information operations, counterterrorism and irregular warfare, energy and sustainability, information assurance and security, and innovation process.

CURRICULA SERVED:

The Institute operates as a federation of research centers and projects, serving a broad community of students and faculty. The Institute does not manage its own curriculum.

RESEARCH:

The Cebrowski Institute’s annual theme projects create focal points for faculty from diverse academic areas to connect and share related research. These theme projects are selected as reflections of issues relevant to national security, with both technical and social dimensions. Around these themes, the Cebrowski Institute organizes research symposia, hosts visiting speakers and collaborators, and facilitates a brown-bag lunch series, all of which serve as hubs for our cross-discipline studies.

In 2005, the Cebrowski Institute’s theme project was W2COG. This research initiative established a consortium to accelerate the DoD’s Global Information Grid (GIG) development. Researchers explored the world of “open” e-business and the worldwide web and applied appropriate lessons to the GIG. W2COG delivered successful process pilots for:

- Rapid, low-cost, objective, expert industry analysis of net-ready issues community of practice (COP) for “semantic data strategy.”
- Rapid demonstration, validation, and fielding of bundled interoperable “net-ready” components designed for the “edge-of-the-GIG” network. These pilots, performed by the members of the functioning consortium, proved the hypothesis that an “open” e-business approach enacted by motivated government, academia, and industry partners can find paths to GIG functionality.

The Cebrowski Institute’s 2006-2007 theme project, Hastily Formed Networks (HFN), was created during the fall of 2005. The HFN project helps to understand the DoD’s emerging, non-traditional new work, whether in stability operations environments like Iraq; humanitarian assistance and disaster relief work, such as the Indonesian Tsunami, Hurricane Katrina, or the Pakistani earthquake; or during the response efforts that occurred during and after 9/11. This project specifically addresses our overall understanding of this critical area, most notably at the intersection of social organization and technical aspects of networking.

CENTERS AND PROJECTS:

- Center for Excellence in Information Operations
- Center for Information Security Research
- Center for Mobile Devices and Communications
- Center for Terrorism and Irregular Warfare
- Cryptologic Research Center
- Hastily Formed Networks Project (Humanitarian Assistance and Disaster Relief; Improvisation; Operational Analyses; Real Options; Swift Trust)
• Autonomous Coordination Lab
• Innovation
• Transformation

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386
Project summaries for Cebrowski Institute faculty members are listed in their respective home departments.
CEBROWSKI INSTITUTE
FOR INFORMATION
INNOVATION AND
SUPERIORITY

2008
Faculty Publications
and Presentations
Publications and presentations for Cebrowski Institute faculty members are listed in their respective home departments.
WAYNE E. MEYER INSTITUTE
OF SYSTEMS ENGINEERING

PAUL SHEBALIN
RADM, USNR (RET.)
DIRECTOR
OVERVIEW:

The Wayne E. Meyer Institute of Systems Engineering was first established as the Institute of Defense Systems Engineering and Analysis in 2001. In May 2002, the Institute was renamed the Wayne E. Meyer Institute of Systems Engineering after RADM Wayne E. Meyer, USN (Ret.), the founding Program Manager of the Aegis Combat System, the first large Navy Surface Warfare acquisition program in which a total systems approach was used in system development and design.

The mission of the Institute is to provide relevant, tailored, and unique research opportunities in systems engineering to support Naval Postgraduate School (NPS) graduate education that increases the combat effectiveness of U.S. and allied armed forces and enhances the security of the United States.

FUNCTIONS:

In meeting the priority needs of our national security stakeholders, the Meyer Institute currently has the following functions:

• Establish and conduct NPS-wide programs in systems engineering research for the Navy, the Department of Defense, and other national security customers that require interdisciplinary teams.
• Foster and encourage all NPS faculty and students to apply their talents to answering the high-priority questions in defense systems engineering.
• Support, facilitate, and enable faculty and students affiliated with the Meyer Institute to conduct sponsored research in defense systems engineering.
• Publicize and share the results of NPS defense systems engineering research.
• Support the assigned Chair Professors – enable the Warfare Chairs and PEO-, Industry-, and other-sponsored Chair Professors to carry out their academic responsibilities.

RESEARCH:

Research supported over the last seven years:

• Twelve Systems Engineering and Analysis student capstone, interdisciplinary research projects in such areas as littoral undersea warfare, port security, and ship-based ABM.
• Littoral Oceanography for Mine Warfare
• Attrition Models for Unmanned Systems
• Deployable Joint Command and Control
• Navy Ship Design
• Safety and Risk-Informed Decision-Making
• Impact Burial Prediction
• Chinese Oceanographic Research
• Technological Surprise in Nuclear Physics
• MDA Field Sensor Experimentation
• Port Security

RESEARCH FACILITIES:

The research facilities that support faculty and students include:

• Faculty offices
• Three integrated student design labs
• Research and study space for 44 students
RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Meyer Institute is provided below:

Size of Program: $1.3M
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THE DEVELOPMENT OF A NAVAL SIMULATION SYSTEM, OPERATIONAL-LEVEL, ANTI-SUBMARINE WARFARE SCENARIO
Jeffrey E. Kline, Senior Lecturer
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To build the capability for faculty and students to use the Naval Simulation System to conduct anti-submarine warfare (ASW) analysis in a classified environment.

SUMMARY: This research produced, developed, and created an operational-level, area ASW scenario within the classified Naval Simulation System at the Naval Postgraduate School (NPS); the scenario will enable faculty and students from the Undersea Warfare, Operations Research, Operations Logistics, Systems Engineering, Combat Systems, MOVES, and Systems Engineering and Analysis curricula to conduct research and evaluation on the impacts of technology advancements and concept-of-operation changes to an area ASW scenario. The scenario is based on a near peer competitor with advanced, maritime anti-access capabilities and a database received from Commander, U.S. Pacific Fleet. The simulation was created in the Naval Simulation System residing in the NPS Secret Laboratories. The first students to begin ASW-related research on this system are expected in 2009.
WAYNE E. MEYER INSTITUTE
OF SYSTEMS ENGINEERING

2008
Faculty Publications
and Presentations
THE MOVES INSTITUTE
(MODELING, VIRTUAL
ENVIRONMENTS, AND
SIMULATION)

RUDOLPH P. DARKEN
DIRECTOR
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 C. Chu, Research Assistant Professor Michael Capps, Associate Professor Donald P. 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, Associate Professor Xiaoping Yun

• Human Factors:
  Research Assistant Barry Peterson, Professor Robert McGhee, Lecturer Eric Bachmann, Associate Professor Rudolph Darken

• Security:
  Associate Professor Cynthia E. Irvine

• Communications/Networks:
  Assistant Professor Geoffrey Xie, Professor Nancy Roberts

RESEARCH THRUSTS:

3D VISUAL SIMULATION


• XML/X3D - Use of Extensible Markup Language (XML) for deploying 3D M&S products over Department of Defense (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.

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, and human perception.

TECHNOLOGIES FOR IMMERSION

- Image Generation - Real-time, computer graphic generation of complex imagery, HDTV, DVD, next generation delivery systems, novel display technologies, and 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, and SimSecurity.

NEXT GENERATION MODELING

- **Navy Cyberspace** - Full end-to-end simulation of the ocean environment, including subsurface, surface, air, and space. Oceanographic datasets 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)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include 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:** $3.4M
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THE MOVES INSTITUTE
(MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION)

2008
Faculty Publications and Presentations
OVERVIEW:

The Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) is a research center at the Naval Postgraduate School. The Office of Naval Research established CIRPAS in the spring of 1996.

CIRPAS provides measurements from an array of airborne and ground-based meteorological, aerosol, and cloud particle sensors, radiation and remote sensors to the scientific community. The data are reduced at the facility and provided to the user groups as coherent datasets. The measurements are supported by a ground-based calibration facility. CIRPAS conducts payload integration, reviews flight safety, and provides logistical planning and support as a part of its research and test projects around the world. The Center operates a variety of manned aircraft and unmanned aerial vehicles (UAV). CIRPAS is also a National Research Facility of UNOLS.

The facility provides unique flight operation and scientific measurement services by:

- Providing access to manned aircraft, UAVs, support equipment, and scientific instruments, thus sparing users the cost of ownership and guaranteeing equal access by all interested parties on a first-come first-served basis.
- Instrumenting and operating aircraft to meet the requirements of a variety of individual research and test programs.
- Developing new instrumentation to meet increasing challenges for improvements in meteorological and oceanographic measurements.
- Calibrating, maintaining, and operating the facility’s airborne instruments in accordance with individual mission specifications.
- Integrating auxiliary payloads as required and handling flight safety and logistics tasks, allowing the user to concentrate on his specific mission goals.

The facility has unique UAV flight services, including:

- 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 30,000 square foot hangar and maintenance and administrative spaces for CIRPAS staff. These include a fully outfitted machine shop, an electronics room, and a calibration lab for the upkeep of scientific instrumentation. The second site is at McMillan Airfield, Camp Roberts, California, 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 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:

- Atmospheric and Oceanographic Research
- Fleet and USIFCOM Exercises
- Support for CONOPS Development
- Payload Test and Evaluation
- UAV Experimentation with Operational Forces supported by analysis provided by NPS Departments and Institutes
THE CIRPAS AIRCRAFT

UV-18A “Twin Otter”: The CIRPAS UV-18A “Twin Otter” has two primary missions. The vehicle’s large, useful load makes it ideal for carrying instrumentation for atmospheric/oceanographic research. The twin turboprop Short Takeoff and Landing (STOL) aircraft can cruise at very low speeds for long durations. The aircraft has a maximum takeoff weight of 13,500 pounds.

Characteristics of the CIRPAS Twin Otter include:

- Maximum endurance of 5 hrs. (extended further during ferry operations)
- Maximum altitude of 25kft
- 70-160 KIAS operational speed range
- 200 amp of payload power (DC and AC combined)
- Wing span of 65 ft.
- GTOW of 13,500 lbs. (~6000 lbs. useful)

Pelican: The Pelican is a highly-modified Cessna 337 Skymaster originally developed by the Office of Naval Research for low-altitude, long-endurance atmospheric and oceanographic sampling. With additional support from NASA’s ERAST Program, the air vehicle has been configured to operate as a UAV surrogate. In the UAV surrogate role, Pelican provides a low-risk, low-cost test and evaluation platform by avoiding the airspace restrictions and other complications associated with unmanned aircraft operations. CIRPAS’ second Pelican air vehicle is a converted Cessna O2-A. It is operated without the Predator avionics equipment and is available for use in support of a variety of generic payload demonstrations.

Characteristics of the Pelican include:

- Maximum endurance of 15 hrs.
- Maximum altitude of 15kft
- Cruise speed of 90 KIAS
- Nose payload bay capacity of 330 lbs.
- Wing hardpoints and cabin space for additional payloads
- 1.2 kW of payload power
- Wing span of 42 ft.
- GTOW of 4600 lbs.

Altus ST UAV: The Altus Single Turbo (ST) UAV was developed by General Atomics ASI to support the high-altitude atmospheric-monitoring requirements of NASA’s Environmental Research Aircraft and Sensor Technology Program. The Altus TM UAV is based on the proven Predator TM and GNAT TM line of unmanned aircraft. The Department of Energy’s Sandia National Labs funded the fabrication of a single-stage, turbocharged Altus TM UAV to support the Atmospheric Radiation Measurement (ARM) Science Campaign. As a result of a cooperative agreement with the DoE, CIRPAS provides the vehicle’s services during the remainder of the year to other users.

Characteristics of the Altus ST include:

- Maximum endurance of 30 hrs.
- Maximum altitude of 45kft
- Cruise speed of 70 KIAS
- Nose payload bay capacity of 330 lbs.
- 1.2 kW of payload power
- Wing span of 55 ft.
- GTOW of 2100 lbs.

Predator UAV: CIRPAS maintains and operates the U.S. Navy’s only two Predator UAVs. One air vehicle is configured with the EO/IR, SAR, and Ku-band SATCOM payloads; the other aircraft has the EO/IR payload only. The Predators and payloads were provided to CIRPAS as a result of the Center’s Tactical Control System (TCS) developmental and operational test support. The air vehicles and payloads are available for other RDT&E or CONOPS development activities on a not-to-interfere basis with the TCS Program Office objectives.
Characteristics of the Predator UAV include:

- Maximum endurance of 36 hrs
- Maximum altitude of 25kft
- Cruise speed of 70 KIAS
- Nose payload bay capacity of 450 lbs., wing hardpoints
- 1.8 kW of payload power
- Wing span of 48 ft.
- GTOW of 2250 lbs.

**GNAT-750 UAV:** The GNAT-750 UAV was developed by General Atomics ASI to support unmanned, medium altitude, endurance surveillance and other sampling requirements. The GNAT-750 is the predecessor to the Predator UAV.

Characteristics of the GNAT-750 UAV include:

- Maximum endurance of 30 hrs.
- Maximum altitude of 18kft
- Cruise speed of 70 KIAS
- Nose payload bay capacity of 125 lbs.
- 1.2 kW of payload power
- Wing span of 35 ft.
- GTOW of 1450 lbs.

**Ground-Control Station:** The General Atomics ASI Ground-Control Station (GCS) provides aircraft control functions for the CIRPAS-operated UAVs. The GCS has redundant Pilot/Payload Operating Stations and is housed in a rugged, 18-foot long wheeled container. CIRPAS currently owns two GCSs and associated Ground Data Terminals capable of operating Predator/Altus/GNAT-750/Pelican air vehicles. GCS #1 includes one UHF and dual VHF radios for communication to other aircraft, range, or ATC personnel. Additional radios provide direct communication between flight crew and other personnel if a requirement exists. GCS #1 also has a video closed-captioning system to overlay aircraft and target position data on imagery before transmission to user.

**Atmospheric/Oceanographic Aircraft Payloads:** CIRPAS can provide use of a wide variety of atmospheric and oceanographic sensors to the research community. The CIRPAS sensor suite includes off-the-shelf instrumentation, as well as one-of-a-kind, custom-built packages. CIRPAS possesses a variety of scientific instruments and instrument suites. The basic meteorological and GPS suite consists of a Rosemount temperature probe, an Edgetech chilled-mirror, a dew-point sensor, a Rosemount flow angle probe with static ports, Vaisala temperature and dewpoint sensors, a Novatel GPS receiver with a ground survey station for differential correction, a TANS Vector GPS attitude system, a CMidget-II INS-GPS system, an IRGA humidity and carbon-dioxide sensor, and an Aerodyne fast absolute humidity sensor. The CIRPAS aerosol instrumentation suite consists of a TSI three-color nephelometer, a radiance soot photometer, a TSI ultrafine particle counter, and a TSI condensation-nuclei counter. The CIRPAS cloud and particle instrumentation suite consists of an FSSP–100, a PCASP-100X (both with upgraded electronics), a CAPS scatter and occultation probes, DMT 2D-P and 2D-PP probes, and a TSI aerodynamic particle spectrometer.
RESEARCH FACILITIES:

Marina Facility

- 30,000 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)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include 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 is provided below:

Size of Program: $4.5M
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<td>Paduan, Jeffrey D.</td>
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<td>Pace, Phillip E.</td>
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CENTER FOR INTERDISCIPLINARY REMOTELY PILOTED AIRCRAFT STUDIES

2008
Faculty Publications and Presentations
CENTER FOR DEFENSE TECHNOLOGY AND EDUCATION FOR THE MILITARY SERVICES

DAVID W. NETZER
DIRECTOR
OVERVIEW:

The Naval Postgraduate School Field Experimentation Program began in FY02 with the goal of providing an opportunity for students and faculty to evaluate some of their latest technologies in an operational environment and, when appropriate, to rapidly transition them to the warfighter. Today the United States Special Operations Command (USSOCOM), the United States Naval Postgraduate School (NPS), and the Biometrics Task Force (BTF) conduct field experiments at multiple locations: Camp Roberts, California; Fort Hunter Liggett, California; Camp Dawson, West Virginia; Camp Atterbury, Indiana; and the ocean/port/riverine area of San Francisco Bay.

The primary objectives of the Field Experimentation Cooperative Program are to experimentally explore the viability of new SOF technology concepts as solutions for identified current and future capability gaps; to provide a venue to rapidly assess, develop, counter, and exploit emerging capabilities; to provide and maintain an evolving, flexible, and adaptive plug-and-play infrastructure; and to provide a unique education and research environment for students and faculty at NPS. Secondary objectives include examining dual-use capabilities for homeland security, stabilization, reconstruction, disaster relief/humanitarian assistance, and for other government agencies.

These goals are accomplished by providing, on a quarterly basis, a unique field experiment venue in which innovation and collaboration between the Department of Defense, government agencies, industry, and universities are encouraged, and in which SOF operator participation and feedback are utilized. The Camp Roberts/Fort Hunter Liggett/Camp Atterbury/Camp Dawson portion focuses on urban and rural terrain, whereas the San Francisco Bay/European and other maritime locations focus on maritime interdiction operations, port security, and riverine operations. The major emphasis at Camp Roberts and Fort Hunter Liggett is on pre-requirements experimentation and rapid response to USSOCOM component command requests. The Camp Atterbury emphasis is on SOF/first responder concepts, training, and evaluations of newly available technologies for near-term utilization. Camp Dawson emphasizes untethered biometrics collection and related communications. USSOCOM SOKF-J9 has been assigned the lead in conducting leveraged experiments in cooperation with the NPS TNT Field Experimentation Program.

CURRICULA SERVED:

The program relies heavily on the operational knowledge of the NPS joint student body, as well as a very close working relationship with USSOCOM. Congressional funding, together with funding from USSOCOM and other government agencies and laboratories, has provided the required support. In FY08, 27 thesis students and 31 NPS faculty from 9 departments and institutes participated, including 21 Ph.Ds. The program supports course projects in several departments and also involves participation from 16 other universities, 33 government organizations, and over 50 companies.

RESEARCH THRUSTS:

Focus is placed on network communications, unmanned systems, biometrics, airspace management and deconfliction, situational awareness, collaborative environments, sensors, and human systems integration.
RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. The CDTEMS program exceeded $2.2M in FY2008. A profile of the sponsored program for the Center for Defense Technology and Education for the Military Services is provided below:

Size of Program: $2.2M
Netzer, David W.
Distinguished Professor and Director
656-2980
dnetzer@nps.edu
CENTER FOR DEFENSE TECHNOLOGY AND EDUCATION FOR THE MILITARY SERVICES

2008
Faculty Publications and Presentations
OVERVIEW:

The National Security Institute (NSI) is a collaboration between the Lawrence Livermore National Laboratory (LLNL; Livermore, California), the Naval Postgraduate School (NPS; Monterey, California) and the University of California at Santa Barbara (UCSB; Santa Barbara, California). The focus of the institute is research and education in support of national security and homeland security.

PARTNERS:

- **Naval Postgraduate School** is an academic institution whose emphasis is on study and research programs relevant to the Navy’s interests, as well as to the interests of other arms of the Department of Defense. The programs are designed to accommodate the unique requirements of the military.
- **Lawrence Livermore National Laboratory** is one of the nation’s foremost applied-science and engineering laboratories. LLNL’s defining responsibility is national security, with missions that include stockpile stewardship, nonproliferation, and multidisciplinary research to enhance national security.
- **University of California at Santa Barbara** houses eight national centers and institutes, with a top-twenty engineering school, five Noble laureates, and substantial federal funding in critical research.

NPS recognizes the contributions of its academic partners in this project. In accordance with federal ethics regulations, however, NPS and the federal government do not endorse any non-federal university, its products, or services.

EXECUTIVE BOARD:

- Dr. Leonard Ferrari, Provost, NPS
- Mr. T.R. ("TR") Komchar, Interim Head of National Security Programs, LLNL
- Dr. Gene Lucas, Executive Vice-Chancellor, UCSB

RESEARCH:

By joining the respective strengths of the partners in research and education, we have a synergistic combination of personnel and facilities. Other national and international institutions may affiliate with the NSI on specific collaborative projects. By combining the exceptional talents of the personnel and the outstanding facilities of these national institutions, we aim to leverage the existing expertise and experience as we seek to combine DoD-focused research and development for national defense with federal/state/local-focused research and development for homeland security.
RESEARCH PROGRAM (Research and Academic)-FY2008:

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. The NSI program exceeded $6.2M in FY2008. A profile of the sponsored program for the National Security Institute is provided below:

Size of Program: $6.2M
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<td>Netzer, David W.</td>
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<td>Michael, James Bret</td>
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<td>Pace, Philip E.</td>
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</table>
COUNTER-IMPROVISED, EXPLOSIVE DEVICES RESEARCH
Gordon H. Bradley, Professor
National Security Institute
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To conduct research on countering improvised, explosive devices (IEDs). Research on the effectiveness of route clearance operations and UAV surveillance has been completed. Ongoing research continues on statistical analysis of route clearance operations, the effectiveness of using UAVs to identify IEDs, preventing IED terror campaigns in the United States, and constructing complex, adaptive systems based on living systems to model insurgencies and their IED systems.

IMPROVISED, EXPLOSIVE DEVICES - RESEARCH AND EDUCATION
Gordon H. Bradley, Professor
National Security Institute
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To conduct research and education on countering improvised, explosive devices (IEDs). The effectiveness of route clearance operations and UAV surveillance will be analyzed. The Naval Postgraduate School SIGACTS Viewer will be used for other analysis. The research supports a graduate seminar on IEDs, with particular focus on countering the networks that support the insurgents.

AN INTRODUCTION TO IMPROVISED, EXPLOSIVE DEVICES (IED) THREAT, DATA, ANALYSIS, AND RESEARCH
Gordon H. Bradley, Professor
National Security Institute
Department of Operations Research
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To offer monthly tutorials (both classified and unclassified) on improvised, explosive devices (IED) threat, data, analysis, and research. The tutorial will be open to Naval Postgraduate School faculty and students. Each tutorial will repeat the same basic information and discuss current IED developments and trends.

LARGE-SCALE OPTIMIZATION
Gordon H. Bradley, Professor
National Security Institute
Department of Operations Research
Sponsor: Office of Naval Research

SUMMARY: This annual proposal for continued support of research in large-scale optimization includes the development and implementation of: a) a new algorithm for solving the binary master problems that appear commonly in the Benders decomposition of important mixed-integer programming models (e.g., network interdiction, defense of critical infrastructure, general capacity-expansion problems); and b) the Naval Postgraduate School SIGACTS Viewer to dynamically display and analyze incident data from Operation Iraqi Freedom, and further development and
ATTRIBUTING THE USE OF BIOLOGICAL WEAPONS AGENTS
Anne L. Clunan, Assistant Professor
Peter Lavoy, Senior Lecturer
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To assess the challenges that policy-makers and military commanders face in correctly identifying and attributing responsibility for the use of biological warfare agents (BW). Looking at past cases from World War II to the present, the project will examine the difficulties involved in knowing when state and non-state actors have employed BW agents, and assessing how governments fared in identifying BW use, managing the information campaign of attribution, and responding to allegations of attacks.

SUMMARY: In 2008, Professor Clunan led and completed the final editing and production of an anthology based on a conference that brought together governmental and non-governmental experts in London from 11-13 July 2006. The edited volume, published by Stanford University Press in 2008, collected expert analysis of confirmed, suspected, and fabricated BW agent releases, and included an assessment of lessons that can be drawn and implemented by current-day policy-makers for managing the problems of BW identification, characterization, and attribution. Professor Clunan conducted research, wrote two chapters, and co-authored a third chapter for the edited volume.

BOOK:

CONTRIBUTIONS TO BOOKS:


KEYWORDS: Biological Weapons, Biological Warfare, Bioterrorism, Biosecurity, Disease, Attribution, Information-Sharing, Proliferation, Nonproliferation, Terrorism, Deterrence, WMD, Weapons of Mass Destruction, Anthrax, Anthrax Attacks, Plague, Germ Warfare, Yellow Rain, Thrips, Japan, India, Korea, Cuba, China, United States, United Kingdom, Biological and Toxin Weapons Convention, Multilateral Treaties

CONTESTED SPACES: THREATS AND RESPONSES
Anne L. Clunan, Assistant Professor
Department of National Security Affairs
Michael E. Freeman, Assistant Professor
Department of Defense Analysis
Sponsor: Center for Stabilization and Reconstruction Studies, Naval Postgraduate School

OBJECTIVE: To assess the challenges that policy-makers face and their responses when confronted with areas that are conventionally labeled as “ungoverned spaces,” or more accurately as “zones of competing governance” or “contested spaces.” The project will consider how ideologies, such as Salafism and
liberalism, have flourished in virtual and physical realms and contributed to the rise of contested spaces. These areas are frequently found in failed or failing states, but also, importantly, in strong states. While most studies of this phenomenon have tended to view it through a geographic lens, this research proposes to broaden the conception of contested spaces beyond the simply geographic realm to include the ideational and virtual realms. The project will focus on the threats posed by radical, ideological movements that thrive in such spaces, and on the responses of states in the broader international context of state sovereignty and global liberalization. The end-product will be a comprehensive dataset mapping the Salafist networks of finances, institutions, and individuals, and a book-length project outline.

**SUMMARY:** Professor Clunan supervised research on the responses of states to contested spaces arising in the area of energy and security and delivered a presentation on the effects of contested spaces and globalization for weapons of mass destruction proliferation.

**PRESENTATIONS:**


**KEYWORDS:** Ungoverned Spaces, Sovereignty, Globalization, Fragile States, Failed States, Failing States, Liberalization, Liberalism, Ideology, Threats, Threat Definition

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**THE DEFINITION OF NATIONAL SECURITY INTERESTS AND INSTITUTIONAL CHANGE**

Anne L. Clunan, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School, Research Initiation Program

**OBJECTIVE:** To investigate how and why post-Soviet Russia defines its national security interests regarding strategic arms control and European security in times of dramatic change.

**SUMMARY:** In 2008, Professor Clunan completed revision of the book manuscript; it was accepted for publication with Johns Hopkins University Press in April 2008.

**PRESENTATION:**


**BOOK:**


**KEYWORDS:** Russia, Security Policy, Foreign Policy, National Interests, NATO, Europe, Former Soviet Union, Nuclear Arms Control, Missile Defenses, Social Psychology, Identity, International Relations Theory, Ingroups, Outgroups
UNGOVERNED SPACES
Anne L. Clunan, Assistant Professor
Harold A. Trinkunas, Associate Professor
Department of National Security Affairs
Sponsor: Center for Civil Military Relations, Naval Postgraduate School

OBJECTIVE: “Ungoverned spaces” are increasingly cited as a key threat to the U.S. government and its interests throughout the world. This project proposes to analyze the concept of ungoverned spaces and determine whether they really are ungoverned and whether they constitute threats to states. Governance exists in areas frequently claimed as ungoverned, such as feral cities, failed states, offshore financial markets, and tribal areas (such as the Afghan-Pakistan border). The notion of ungoverned spaces is potentially even more broadly applicable to areas within otherwise functioning states, including the United States, where authority and jurisdiction are exercised by non-state actors. This ongoing project brings together international scholars with a broad interest in the problem of “ungoverned spaces,” including work focused on megacities, organized crime, transnational gangs, “home-grown” terrorist cells, money laundering, WMD proliferation networks, the privatization of security services, and the rise of Internet social movements. The principal participants continue to contribute to an edited volume on the subject of ungoverned spaces.

SUMMARY: Professors Clunan and Trinkunas organized a major, ongoing research project in 2007 regarding the threats posed by ungoverned spaces, including a conference held at the Naval Postgraduate School from 2-3 August 2007. The conference was co-sponsored by the Center for Civil Military Relations at the Naval Postgraduate School and the Defense Threat Reduction Agency/Advanced Systems and Concepts Office. In 2008, Professors Clunan and Trinkunas edited and commented on all participants’ papers and submitted the volume for review by the Stanford University Press.

PRESENTATION:


UNGOVERNED SPACES
Anne L. Clunan, Assistant Professor
Jessica Piombo, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To assess the command and control challenges that civilian and military planners face when dealing with “ungoverned spaces” and the weapons of mass destruction (WMD) proliferation and terrorism threats that arise from them. Ungoverned spaces are increasingly cited as a key threat to the U.S. government and its interests throughout the world. Often these spaces are seen as synonymous with failed states, or states that are unable to effectively exercise sovereignty. A key goal of U.S. defense strategy is to improve “effective sovereignty” in such areas, in order to deny sanctuary to WMD proliferators, terrorists, arms- and narco-traffickers, and gangsters. This project will expand our understanding of ungoverned spaces beyond the commonplace notion of “failed,” “failing,” or “fragile” states to address spaces within otherwise functioning states that may harbor WMD proliferation networks or facilitate WMD terrorism. It will investigate which ungoverned spaces are priority threats to the United States and its allies. It will conclude with an analysis of early warning indicators and policy-makers’ and military planners’ attempts to manage the WMD proliferation and terrorism threats arising from ungoverned spaces in Africa, Asia, Eurasia, and the Americas.
SUMMARY: In this ongoing project, Professor Clunan commissioned a series of research papers from subject-matter experts, including Professor Piombo, to assess cases of ungoverned spaces around the world; examine early warning indicators of ungovernability, WMD proliferation, and WMD terrorism networks; and analyze how military and civilian governmental agencies have responded in the past to WMD threats arising from ungoverned spaces. These papers were delivered at the Conference on Ungoverned Spaces, which was co-organized by Professors Clunan and Trinkunas and held from 2-3 August 2007 at the Naval Postgraduate School. Professor Clunan presented findings for policy-makers and military planners in 2008.

PRESENTATION:


KEYWORDS: Ungoverned Spaces, Sovereignty, Globalization, Fragile States, Failed States, Failing States, Proliferation, WMD, Weapons of Mass Destruction, Threats, Threat Definition
**CONFERENCE PUBLICATIONS**


**CONFERENCE PRESENTATIONS**


**BOOKS**


**CONTRIBUTIONS TO BOOKS**


CENTER FOR ASYMMETRIC WARFARE

JOYCE BORGEN
DEPUTY DIRECTOR
OVERVIEW:

The Center for Asymmetric Warfare (CAW) is a new research center at the Naval Postgraduate School (NPS) that predicts vulnerabilities in homeland defense and researches, develops, and tests protections.

The CAW is a federal government organization that was established in 1999 in recognition of the need to support U.S. military forces and local/state/federal organizations in identifying, countering, and controlling the effects of asymmetric warfare (AW) in support of the Global War on Terrorism. The CAW has since established itself as a leader in its field.

The CAW is committed to providing the best exercises, training, technology, and education in an integrated environment in an effort to enable participants to achieve their goals and objectives.

In 2008, the CAW joined NPS as a satellite division, located at Point Mugu, California, and aligned under the NPS Research Department. As part of the Research Department, the CAW has the flexibility to operate across the four institutes and four schools of the Naval Postgraduate School. It also allows the CAW to capitalize on the expertise of NPS’ many distinguished alumni, faculty, and students, who can perform as interns.

The CAW builds exercises that include participants from local, state, federal, Department of Defense (DoD), military, and private sector entities.

The CAW offers a multi-faceted team that has experience in state and local emergency management and military exercise planning and execution, with an emphasis on domestic and international port security and force protection.

CORE CAPABILITIES:

- **Training** - Recognized subject matter experts develop and deliver a wide variety of student-based training courses, including the National Incident Command System (NIMS), the Incident Command System (ICS), and Defense Support of Civil Authorities (DSCA).
  
  The CAW also provides training in specific areas of the exercise design process, such as identification of exercise requirements and development of the Exercise Master Scenario Events List (MSEL).

- **Exercise Design** - Facilitation of multiple and diverse response and support agencies with different operational characteristics and cultures to identify the procedural, physical, and logistics needs for the successful execution of an exercise. This leads to the development of complex but realistic scenario-based challenges that meet the goals and objectives of the participating agencies.

- **Exercise Delivery** - Management of the exercise activities, including set-up of the environment, conducting and controlling exercise activities, preventing peripheral events from disrupting the exercise, and facilitating participating agencies’ responses to the scenario events for capturing lessons learned and best practices.

- **Exercise Documentation** - The CAW is experienced in producing the full spectrum of exercise documentation, including training, design, control, execution, instructional aides, and after-action documents.

- **Resources** - Personnel, products, and/or locations that enhance the realism of the scenario and the learning experience, ranging from:
  
  - Simulated weapons and explosives
  - Large-scale props, such as ships, aircraft, and buildings
  - Opposition forces
  - Simulated casualties
  - Contaminated victims
  - Video production to support the exercise scenario or capture and document exercise activities
  - Press/media representatives
  - Fast Patrol Craft, CAW-1
**GROWTH:**

The CAW continues to expand its core capabilities and can tailor programs to suit an individual organization’s needs.

**RESEARCH PROGRAM (Research and Academic)-FY2008:**

The Naval Postgraduate School’s sponsored program exceeded $105 million in FY2008. Sponsored programs include both research and educational activities funded from an external source. The CAW program exceeded $1.2M in FY2008. A profile of the sponsored program for the Center for Asymmetric Warfare is provided below:

![Pie Chart](image-url)

**Size of Program: $1.2M**
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<td>Navy Programs</td>
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<td>Powell, Craig</td>
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CENTER FOR ASYMMETRIC WARFARE

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NAME
DEPUTY DIRECTOR
OVERVIEW:
UNGOVERNED SPACES CURRICULUM DEVELOPMENT
Harold A. Trinkunas, Associate Professor
Anne L. Clunan, Associate Professor
Center for Contemporary Conflict
Sponsor: CCMR

OBJECTIVE: To develop curriculum materials for courses on ungoverned spaces provided to international students as part of reimbursable education programs.

SUMMARY: This project analyzed the concept of ungoverned spaces and determined whether they really are ungoverned and when they may constitute threats to states, global governance, and human security. The essential issue is not lack of governance, but rather who governs these spaces. Governance exists in areas frequently claimed as ungoverned, such as feral cities, failed states, offshore financial markets, and tribal areas (such as the Afghan-Pakistan border), yet it is mostly exercised by non-state actors. The notion of ungoverned spaces is potentially even more broadly applicable to legal, functional, virtual, and social arenas that are either not controlled by states or are contested by non-state actors and spoilers. These spaces can prove inimical to state interests because they provide avenues for the flow of illicit resources, persons, and information.

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