# Weapons and Systems Engineering Department

Professor Carl E. Wick
Chair

Research activity within the Weapons and Systems Engineering Department not only provides the faculty with an opportunity to grow professionally and to keep abreast of rapidly advancing systems technology, but it also helps to ensure that the department's academic program continuously reflects current engineering state-of-the-art systems and practice. Every faculty member in the department, both civilian and military, participates in research in areas of interest to the U.S. Navy, and/or supports midshipmen research programs in an advisory capacity. Faculty research areas currently include controls, tracking algorithms, metrology, robotics (including autonomous vehicles, vehicle swarms, computer vision), and ship power systems survivability. Funding sources for faculty research are as diverse as the projects themselves. This year's major sponsors included the Office of Naval Research (ONR), the Naval Research Lab (NRL), and the National Institute of Standards and Technology (NIST).

Every graduating Systems Engineering major participates in a research, design, and development "capstone" project for the purpose of realizing the practical application of systems theory that they have studied in majors' classes. A capstone experience is part of program accreditation requirements. Faculty advisers are assigned to project teams of typically two or three midshipmen. Faculty advisors provide support of a technical nature, and they emphasize planning, scheduling, and effective oral and written presentation of project results. Midshipmen teams present their projects during a two week period at the end of the spring semester. Typical examples of midshipmen research projects include development of autonomous carts and boats, automatic target detection, tracking, and control. Several students in the major engage in additional independent research course projects, where they are paired with faculty that have expertise in their proposed research area. Many of these independent research projects result in papers that are published in journals or are published and presented at technical conferences.

This year, there was one Trident Scholar in the Systems Engineering Department, who worked on a project involving the control of a small autonomous surface vehicle. Trident scholars engage in an extensive research project in lieu of several courses. They are closely monitored and advised in their research by faculty advisors and by other faculty constituting the Trident Committee. Their research work is published locally and often results in articles published in technical journals and presented at external conferences. Trident students report their findings at a special year-end conference.

## Sponsored Research

### Atlantic Center for the Innovative Design of Small Ships

Researcher: Associate Professor Bradley E. Bishop
Sponsor: Office of Naval Research (ONR)

Novel hull designs and locomotive capabilities for littoral craft require substantial automation in order to achieve minimum manning, maximal power efficiency and optimal performance. Additionally, automation can be used to enhance safety and minimize environmental impact. The primary focus of this project was to provide an updated toolbox of systems engineering methods for enhanced littoral operations.

This effort had three distinct components. Component I involved coordination of a swarm or platoon of cooperating autonomous surface vessels for enhancing security and providing both reconnaissance and force projection. Component II involved the application of control theory to stability and control problems for small craft in littoral zones. Component III involved design, construction and fielding of a fully instrumented autonomous surface vessel.

## Distributed Manipulation of Large Objects on the Water by Swarms of Autonomous Surface Vessels

Researchers: Assistant Professor Joel Esposito, Assistant Professor Matthew G. Feemster and Captain John W. Nicholson, USN
Sponsor: Office of Naval Research (ONR)

The goal of this project was to allow a single human operator to control and supervise the on-water manipulation of large objects using swarms of autonomous surface vessels. Swarms – large groups of relatively simple and cheap robots working in concert without a centralized decision maker – have been a popular area of research over the past few years. However, few works actually address the issue of how swarms can affect changes in their environment. On-water manipulation of large objects by a swarm of small autonomous vehicles is a relatively novel area of investigation with naval applications to marine ordinance disposal, transportation of disabled ships, and assembly of large marine structures such as positioning sonar arrays for littoral surveillance or construction of off-shore platforms and bases. Aside from these direct applications, the methodology developed will have indirect application to land-based robot swarms, swarm reconnaissance and exploration missions, and micro-assembly tasks.

## An H-Infinity-based Detection and Tracking Method for Underwater Sensor Systems

Researchers: Associate Professor Kiriakos Kiriakidis and Associate Professor Richard T. O'Brien, Jr.
Sponsor: Office of Naval Research (ONR)

This project focused on two topics: (1) the design of real-time target tracking and detection algorithms based on worst-case minimization and (2) performance enhancement and convergence analysis of these algorithms, particularly, in the case of arbitrary array geometry and broadband signals. The development of target information algorithms will proceed in three stages: (a) assuming target detection, a target parameter estimator was developed using multiple models for the signal and the target kinematics, (b) the estimator was modified to incorporate target detection, and (c) a time-varying parameter estimator for the signal was developed, but without an underlying kinematic model for the target. To reduce the estimation error, the minimization of a weighted worst-case performance criterion was investigated. To provide for analysis of the algorithms, recent results on time-varying stochastic regression will extend to the proposed robust estimator. The "transition potential" of the algorithm was evaluated on a group of autonomous vehicles that, equipped with sonar sensors, form an array of variable and potentially adaptable geometry.

## Atlantic Center for the Innovative Design and Control of Small Ships: Vision-based Wave Sensing

Researchers: Associate Professor Jennifer K. Waters (Naval Architecture and Ocean Engineering Department) and Associate Professor Jenelle A. Piepmeier
Sponsor: Office of Naval Research (ONR)

The Atlantic Center for Innovative Design is a consortium of individuals from the Stevens Institute of Technology, University College of London, Webb Institute, the U.S. Naval Academy, and a number of industry partners. The Center proposed to address and meet the Navy's new and emerging needs in the littoral zone by focusing on two key areas. The current research investigated vision-based sensing methods to provide sea state estimation for improved sea-keeping. Work during the summer of 2004 investigated the feasibility of a vision-based wave sensing approach that was able to determine pertinent wave characteristics, such as slope, height, and frequency. A stereo vision-based system was successfully applied to measure the water surface of the Severn River in Annapolis, Maryland. Surface plots were generated and significant wave heights were computed for a variety of camera angles and resolutions. Validation of this data was obtained by a conventional wave probe. Work during the

fall of 2004 included testing at Carderock NSWC wind-wave tank. Current research is investigating vision-based sensing methods to provide water surface measurements for vessel wake studies at USNA.

## Flight Control Development for the Samara Rotary/Fixed Wing Micro Air Vehicle

Researcher: Associate Professor George E. Piper
Sponsor: Naval Research Laboratory (NRL)

The Naval Research Laboratory (NRL) is developing a group of micro air vehicle (MAV) concepts intended for operation in urban or other confined environments. Primary flight requirements for these MAVs are low speed maneuverability, vertical takeoff and landing, and the potential for hovering. In particular there is interest in an MAV that can land or "perch" in remote locations and then take to the air again. This interest has led to the development of a novel rotary/fixed wing air frame configuration called Samara. The novel Samara airframe configuration possesses unique flight characteristics and control issues. Understanding the flight phenomenon of this vehicle is critical for the development of a flight control system. The researcher is working with NRL to characterize the flight dynamics and to develop practical flight control system for the Samara aircraft.

## Electric Ship Integration

Researchers: Associate Professor Edwin L. Zivi
and Assistant Research Professor Yonggon Lee
Sponsor: Office of Naval Research (ONR)

This is the final year of this four year research program contributing to the U.S. Navy's push towards an Electric Naval Force. The Academy investigators are part of a collaborative effort that includes faculty from the Massachusetts Institute of Technology and Purdue University. More specifically, the effort involves the integration of research, analyses, software and hardware tools, monographs, and curricula to support multidisciplinary ship design, power system analysis, and automation engineering. USNA leads the Automation and Systems Engineering thrust including establishment of an automation systems research laboratory located at the Naval Academy. The primary closeout work involved the installation and integration of a significant computational upgrade to the Academy's Automation laboratory. The upgrade consists of a Linux "Beowulf" computer cluster composed of 34 dual-core AMD Opteron processors. The open-source pMatlab (see http://www.ll.mit.edu/pMatlab/) and MatlabMPI (see http://www.ll.mit.edu/MatlabMPI/) software packages have been adapted to provide a transparent parallel processing interface to the MATLAB Genetic Optimization System Engineering Toolbox (GOSET). GOSET software, documentation and training are disseminated and supported jointly by Purdue University and the Naval Academy.

## Distributed Automation Design for Survivability

Researchers: Associate Professor Edwin L. Zivi
and Assistant Research Professor Yonggon Lee
Sponsor: Office of Naval Research (ONR)

This research involves the derivation and demonstration of novel "system of systems" design methods, metrics and tools in collaboration with Purdue University, the Massachusetts Institute of Technology Ocean Engineering Department, and the Georgia Institute of Technology Aerospace Systems Design Laboratory. This methodology emphasizes design attributes which provide continuity of vital services. Specifically, operability has been mathematically defined as the system's ability to provide continuity of distributed services to vital loads with respect to a particular casualty induced damage disruption. By extension, dependability has been defined in terms of operability over a distribution of likely damage disruption scenarios. Recent modeling and simulation efforts have focused on the derivation and implementation of the fluid transport thermal management system. The overall time domain simulation captures the propagation of failures throughout the dynamically interdependent electro-mechanical-thermal ship systems. Numerical results demonstrate the ability to genetically optimize electric warship integrated engineering plant operability and dependability with respect to combat induced disruption.

### Nonlinear Power System Stability Criteria

Researchers: Associate Professor Edwin L. Zivi
and Assistant Research Professor Yonggon Lee
Sponsor: Office of Naval Research (ONR)

Future warships will depend on the continuous, stable operation of highly nonlinear, dynamically interdependent networks of intelligent power producers, distribution equipment and vital loads. The design and control of these integrated fight through power systems is complicated by the competing goals of achieving tight power regulation and minimizing harmonic distortion while maintaining system stability. The global stability question is further complicated by finite inertia considerations, load variations which are large relative to the generating capability, the nonlinearity of the system dynamics, system modularity, and the complexity of variable structure reconfiguration due to battle damage. The goal of this research is to extend the existing state-of-the-art in power system stability analysis of isolated power systems. The ultimate goal is a methodology to specify decomposable stability specifications which guarantee system stability. This would allow subsystem designers, ship systems integrators and the Navy to specify interface standards which ensure stability of dynamically interdependent, energetic systems. The derivation of decomposable interface specifications is motivated by recurring problems which have been uncovered during the integration of prototype power systems and the resulting high integration risk associated with future systems. Initial research focused on potential extensions to small-signal methods, which, while useful, fail to give a measure of the robustness of an operating point. Subsequently, research has shifted to the second approach: evolutionary computing techniques for maximizing the Lyapunov region of attraction (ROA) around an operating point.

## Independent Research

### Test Generation for Embedded Control Systems

Researcher: Assistant Professor Joel M. Esposito

The fundamental idea behind this research is to create an algorithm whose inputs are: a model of the control system being tested, along with initial conditions; and the specification which it is being tested against. The output of the algorithm is a set of open loop test input functions which represent a minimal set of test scenarios required to determine with within some confidence interval if the system meets the specification. The primary motivation behind developing such a method is to avoid the time, expense and inconclusiveness of trial and error testing by using automated rigorous tools to guide the design process. The notion of a test generator and test adequacy criteria, defined for software testing, are formalized for control systems in terms of the maximum principle. A method from randomized robot motion planning, Rapidly Exploring Random Trees (RRT,) is modified and applied to this problem. Modifications are centered on the difficulties associated with testing uncontrollable systems.

### Motion Control of Swarm Robots for Robust Wireless Communication

Researcher: Assistant Professor Joel M. Esposito

Swarms of robots must employ distributed motion control algorithms to effectively achieve their objectives; however many objectives cannot be accomplished without some communication and coordination among the swarm members. While completing their primary task the robots must therefore also maintain a robust mobile wireless network among themselves. For the purposes of this project, doing so implies each robot should maintain proximity and line of sight to two or more swarm members at all times. The project created individual control laws for range and line of sight, an algorithm for composing the velocities suggested to achieve the many disparate objectives, and analysis of the natural topology of the emerging configurations.

# Trident Scholar Project

## Design and Implementation of an Autonomous Surface Vessel (Trident Report # 346)

Researcher: Midshipman 1/C Caleb M. Reed, USN
Advisers: Associate Professor Bradley E. Bishop
and Associate Professor Jennifer K. Waters (Naval Architecture and Ocean Engineering Department)
Sponsor: Office of Naval Research (ONR)

Autonomous vehicles are only beginning to make the impact that they soon will have in a variety of applications. Research is ongoing to provide unmanned vehicles with higher cognitive abilities in order to simplify or eliminate the role of an operator. Advancement in the understanding and development of Autonomous Surface Vessels (ASVs), the objective of this research project, will be beneficial to not only the military, but also in many commercial and research applications.

Multiple criteria were considered in selecting the type of vessel and maneuvering hardware that would be most appropriate for the desired applications. A semi-planing monohull with an electric motor and single rudder was selected as the test bed for this research. In addition, sensors were chosen that would provide the necessary data for an autonomous controller. These sensors were integrated onto a single circuit board which included a dedicated microprocessor for their operation and control. Different communication techniques were investigated to allow the primary microprocessor to pass information to a secondary microprocessor which produced the output for the control motors.

Techniques for mathematically modeling the vessel were investigated, and physical experiments were conducted to determine the maneuvering parameters of the vessel, required for the model's development. From this model, a control system was developed to guide the vessel to a desired position following waypoints based on the input of the sensors. These waypoints were automatically determined from information stored on an off-board computer. Data was collected in order to improve the functionality of the sensors and navigational techniques.

During this research, numerous challenges specific to small, low-cost ASVs were encountered and investigated. In the end, a fully functional low-speed miniature ASV was developed and tested in the waters surrounding the U.S. Naval Academy. This platform represents an important step forward in autonomous marine surface vessels

# Bowman Scholar Projects

## Digital Control of Magnetic Bearings

Researcher: Midshipman 1/C Alan M. Marsh, USN
Advisers: Associate Professor George E. Piper,
Assistant Professor Matthew G. Feemster and Captain Owen G. Thorp, III, USNR
Sponsor: Bowman Scholar Program (BSP)

Active Magnetic Bearings have many applications and provide many benefits to industrial, military and research. Some of the benefits of active magnetic bearings are frictionless bearings requiring no lubrication, reduces wear on machinery and reduces noise. The first years of implementing active magnetic bearings, analog controllers were primarily used due to the need of rapid responses to the system inherent instability and lack of computer power. With the advancement of computers, digital controllers are possible to be fast enough to implement magnetic levitation. This paper describes the set-up of a digitally controlled active magnetic bearings system. Analog versus digital designs are discussed with the advantages and disadvantages to both methods of control.

### Power Automation

Researcher: Midshipman 1/C Daniel S. Shevenell, USN
Advisers: Associate Professor Edwin L. Zivi and Associate Professor John G. Ciezki
Sponsor: Bowman Scholar Program (BSP)

This project involved the design of a low voltage, low power model of a Ship Service Converter Module (SSCM) for a bench top DC zonal electrical distribution system (DC-ZEDS) testbed. The SSCM is essentially a Pulse-Width-Modulated (PWM) "buck chopper" DC-DC converter were the output filter inductance and capacitance are chosen to maintain continuous inductor current and to provide acceptable voltage ripple. The research included the design of closed-loop Proportional-Integral-Derivative (PID) converter controls capable of regulating SSCM output despite fluctuations in supply voltage and loading. SIMULINK® time domain simulation results where used to predict SSCM perform.

### Development of a PC104 Control Environment

Researcher: Midshipman 1/C Jonathan A. Shaver, USN
Adviser: Assistant Professor Matthew G. Feemster
Sponsor: Bowman Scholar Program (BSP)

Currently two common avenues for control strategy implementation exist: i) PC based implementation or ii) DSP/PIC/microprocessor based implementation. The PC approach offered the highest level of user interface and data storage yet does not lend itself easily for integration in mobile applications. If implementing a control design with a DSP/PIC/microprocessor, one may encounter such issues as data logging limitations and the requirement of an additional host PC to develop and compile the target's program. To address these issues, a PC104 based control environment was developed that facilitates rapid prototyping of research oriented control strategies through the development of an environment that: i) requires only the PC104 for code development and implementation, ii) lends itself for utilization in mobile applications, iii) provides means for data logging, and iv) can be interfaced via wireless means.

## Midshipman Research Course Projects

### Modeling of the Arterial Baroreceptor Reflex

Researcher: Midshipman 1/C Hannah G. Jayroe, USN
Adviser: Associate Professor Kiriakos Kiriakidis

The intent of this research was to study the reflex dynamics of the arterial baroreceptors and design a simulation that mimics the behavior of this reflex. The paper presented the basics of the circulatory system, the function of the baroreflex, and the design of models studied. Also, the effect of different inputs into the model to evaluate behavior of the reflex when it is diseased or affected by other conditions was discussed. My course of objectives was to learn about the reflex, as it is a complicated physiological mechanism, model it qualitatively, study existing models of the baroreflex, and design my own model. Subsequently, certain forms of diseased baroreceptors and their behavior in the model were presented. Comparing the results of the simulation of a normal physiological model to a diseased model was predictable based on data researched. This research should be helpful in understanding a mechanism in the human body which is not already well understood and how it affects the system when it dysfunctions. It is my intention to be able to model the system effectively enough such that it can be used to compare against patient data and actually help diagnose a medical problem based on the comparison.

### An Investigation of Interceptor Guidance Methods through Modelling and Simulation

Researcher: Midshipman 2/C Philip Johnson, USN
Adviser: Associate Professor Richard T. O'Brien, Jr.

Multiple types of guidance methods for ballistic missile interceptors currently exist. The purpose of this research project was to develop techniques that identify how guidance methods respond under a variety of different initial conditions. This data has contributed to the evaluation of guidance method performance given a set of initial

conditions such as initial range, target velocity, interceptor velocity, and line of sight (LOS) angle. Several types of homing logic including pursuit, constant bearing, line-of-sight, and proportional navigation were studied to gain familiarity with previous work in this field. Proportional navigation and angular acceleration guidance were modeled using computer simulations in SIMULINK®. To date, the computer models have allowed for exploration of the response of each type of guidance to similar constant velocity interceptions.

### Image Processing of Sidescan Sonar

Researcher: Midshipman 2/C Richard Mayfield, USN
Adviser: Captain John W. Nicholson, USN

The purpose of this project was to create a Graphical User Interface (GUI) that is capable of decoding and analyzing sidescan sonar data. The GUI was implemented in MATLAB® due to its image processing features. The GUI reads sidescan sonar files in the Marine Sonics MSTIFF data file format, displays the image, adjusts color, automatically detected the bottom, and performed slant-range correction. Real-time processing of stored images is simulated by reading in image lines at a user-defined pulse repetition frequency.

### Autonomous Convoy

Researcher: Midshipman 1/C Christopher McCook, USN
Advisers: Associate Professor Richard T. O'Brien, Jr. and Assistant Professor Joel M. Esposito

Unmanned vehicle technology has progressed with incredible speed and increasing capability within the last few years. Unmanned vehicles are thus becoming more and more integrated into U.S. military service. Most unmanned vehicles, however, still require some level of direct human control in order to complete missions traditionally done by people. The goal of this semester's research was to develop a framework for a fully "Autonomous Convoy." This convoy would require no human control while en route to its destination. Furthermore, the convoy would be able to dynamically respond to attacks and ambushes by moving high-value units away from a kill-zone while at the same time using armed units to eliminate an enemy threat. All of these ground units would be tied to each other and to over-flying Unmanned Aerial Vehicles (UAV's) through a robust wireless network. While this network would enable the dynamic response to an enemy, as well as a more efficient route-to-target, every unit in the convoy would maintain the ability to guide itself autonomously if necessary.

### An Investigation of a Robust Swing-Up Control Design for a Rotary Inverted Pendulum

Researcher: Midshipman 1/C Serena N. Tyson, USN
Advisers: Associate Professor Richard T. O'Brien, Jr. and Assistant Professor Matthew G. Feemster

In this research, a comprehensive study of the swing-up controller design for a rotary inverted pendulum was considered. Specifically, the scope of this paper was the evaluation of an energy based swing-up control strategy on a common experimental platform in an effort to determine performance and robustness characteristics with respect to parameter and model uncertainty. Results from this investigation will serve as a foundation from which further research will be conducted into the development of a robust swing-up control strategy.

## Midshipman Design Projects

### Tracking Paint Ball Gun

Researchers: Midshipmen 1/C Lindsay J. Adlam, Zachary N. Capacete,
Ian P. Fisher and Scott A. Robertson, USN
Adviser: Lieutenant John R. Augenblick, USNR

### Shoulder-Mounted Point and Shoot

Researchers: Midshipmen 1/C Maksudul A. Ali, Kevin E. Laughary,
Samuel M. Marrone and David M. New, USN
Adviser: Associate Professor Svetlana Avramov

**Systems Ball**
Researchers: Midshipmen 1/C Matthew W. Alt, John P. Franklin
and Christopher V. Hermeling, USN
Adviser: Commander Kurt H. Statts, USNR

**Autonomous Aerial Vehicle**
Researchers: Midshipmen 1/C Benjamin P. Anderson,
Darren P. Jacques and Thomas J. Younghans, USN
Adviser: Associate Professor George E. Piper

**Target Recognition System**
Researchers: Midshipmen 1/C Cyrus K. Anderson
and Joseph B. Martin, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

**Portable Tazer**
Researchers: Midshipmen 1/C Nathan B. Anderson and
Reginald B. Cruz, USN
Adviser: Lieutenant Commander William S. Pendergrass, USN

**Target Acquisition System**
Researchers: Midshipmen 1/C Cody J. Bench, Serkan Calimli
and Derek J. Herrera, USN
Adviser: Professor Terrence E. Dwan

**Remote Sentry Weapon System**
Midshipmen 1/C Brad M. Berthelotte, Anthony J. Doukas
and Patrick M. Gillen, USN
Adviser: Professor Terrence E. Dwan

**Closed Loop Sound Enhancement**
Researcher: Midshipman 1/C Joshua S. Bettis, USN
Adviser: Associate Professor Edwin L. Zivi

**Rob-Achnid**
Researchers: Midshipmen 1/C Nicholas J. Bourgeois, Joseph S. Huck,
Jenny Li, Casey D. Nelson and Allan T. Phillips, USN
Adviser: Professor Terrence E. Dwan

**SAE**
Researcher: Midshipman 1/C Burnes C. Brown, USN
Adviser: Associate Professor Jenelle L. Piepmeier

**DBF Aerial Vehicle**
Researchers: Midshipmen 1/C Gregory D. Calloway, Joseph M. MacDonald
and Lloyd G. Patterson, USN
Adviser: Associate Professor George E. Piper

**Systems Ball**
Researchers: Midshipmen 1/C James B. Cantrell and
Stephen D. Szachta, USN
Adviser: Lieutenant Commander Gwen D. Clifford, USNR

## Helicopter Attitude Control

Researchers: Midshipmen 1/C William M. Carson and
Peter C. Kennedy, USN
Adviser: Professor Kenneth A. Knowles

## Voltage Stabilizer

Researchers: Midshipmen 1/C Robert C. Casper and
Wes E. Urquhart, USN
Adviser: Professor Edwin L. Zivi

## Autonomous Foosball

Researchers: Midshipmen 1/C Kuan Yu Chung, Lewis R. Emery
and Damian G. Oslebo, USN
Adviser: Associate Professor Bradley E. Bishop

## Autonomous Underwater Vehicle

Researchers: Midshipmen 1/C Patrick R. Collins, Samual S. Fromille,
Cecilia X. Hu, Christopher T. James, Christopher R. Karapostoles, Joseph R. Nelson
and Brett R. Vining, USN
Advisers: Captain John W. Nicholson, USN
and Lieutenant Roger S. Cortesi, USNR

## Point and Shoot Video Game

Researchers: Midshipmen 1/C Carl W. Davis and
Clayton R. Heyward, USN
Adviser: Commander Kurt H. Statts, USNR

## Inverted Pendulum on Cart

Researchers: Midshipmen 1/C Michael J. Eckert and
Albert F. Silva, USN
Adviser: Assistant Professor Matthew G. Feemster

## Urban Combat Vehicle

Researchers: Midshipmen 1/C Clinton D. Emrich and
Nisa M. Halsey, USN
Adviser: Lieutenant Shane A. Crockett, USNR

## Self-Balanced Scooter

Researchers: Midshipmen 1/C Michael Feagans and
Eric D. Shuey, USN
Advisers: Associate Professor Richard T. O'Brien, Jr. and
Assistant Professor Matthew G. Feemster

## Autonomous Golf Cart

Researchers: Midshipmen 1/C Jonathan R. Ferrell, Justin P. Kirkpatrick,
Luke J. McLearen and Evan M. McNeer, USN
Advisers: Associate Professor Richard T. O'Brien, Jr. and
Lieutenant Colonel Randy P. Broussard, USAF

## Bartender (aka Lazy Dog)

Researchers: Midshipmen 1/C Patrick J. Flores, Michael A. Schenk
and Samuel M. Spletzer, USN
Adviser: Lieutenant William S. Pendergrass, USN

**Unmanned Aerial Vehicle**
Researchers: Midshipmen 1/C Toni L. Gaither and
Danielle A. Garcia, USN
Adviser: Professor George E. Piper

**Systems Ball**
Researchers: Midshipmen 1/C Stephen E. Griffing, Stephen E. Miller
and Colin S. McFerran, USN
Adviser: Lieutenant Curtis L. Hamilton, USNR

**Lagrangian Drifter Buoy**
Researchers: Midshipmen 1/C Sean M. Harrington and
Daniel G. Summers, USN
Adviser: Associate Professor Jenelle L. Piepmeier

**The Lacrosse Tracker**
Researchers: Midshipmen 1/C Elizabeth Q. Holmes and
Stephen R. Miggins, USN
Adviser: Assistant Professor Joel M. Esposito

**Systems Ball**
Researchers: Midshipmen 1/C Daniel D. Huynh, Matthew C. Mangaran
and Joshua H. Tiley, USN
Adviser: Lieutenant Commander Gwen D. Clifford, USNR

**Drink Fetching**
Researchers: Midshipmen 1/C Nicholas S. Jackson and
Benjamin N. Stickler, USN
Adviser: Associate Professor Kiriakos Kiriakidis

**DBF Aerial Vehicle**
Researchers: Midshipmen 1/C Hannah G. Jayroe, Kurt E. Laughary
and Kevin R. Sartain, USN
Adviser: Associate Professor George E. Piper

**Semi-Autonomous IR Locator**
Researchers: Midshipmen 1/C Michael D. Kattula, Mark A. Torres
and Bradley S. Williams, USN
Adviser: Associate Professor Svetlana Avramov

**Autonomous Micro Air Vehicle**
Researchers: Midshipmen 1/C Eric V. Kjono and
Gregory B. Storer, USN
Adviser: Associate Professor George E. Piper

**Point and Shoot Potato Gun**
Researchers: Midshipmen 1/C Carl J. Krueger, Shawn C. Lang
and Luis A. Levine, USN
Adviser: Lieutenant Commander Craig M. Payne, USNR

**Skydiving Judge**
Researcher: Midshipman 1/C Andrew G. Lichtenstein, USN
Adviser: Associate Professor Jenelle L. Piepmeier

## Magnetic Levitation
Researcher: Midshipman 1/C Alan M. Marsh, USN
Adviser: Associate Professor George E. Piper

## Telerobotic System
Researcher: Midshipman 2/C Brian D. Maxfield, USN
Adviser: Professor Kenneth A. Knowles

## Differentially Driven Vehicle
Researchers: Midshipmen 1/C Federico W. Mendizabal and Kevin A. Raspet, USN
Adviser: Associate Professor Kiriakos Kiriakidis

## Autonomous Sentry Gun
Researchers: Midshipmen 1/C Jeffrey M. Menne and David A. Pilko, USN
Adviser: Lieutenant Commander Craig M. Payne, USNR

## Shape-Shifting Spider-Bot
Researchers: Midshipmen 1/C Michael S. Moorse, Beau S. Portillo, Thomas F. Schmitz and Hayden T. Stevens, USN
Adviser: Associate Professor Kiriakos Kiriakidis

## FIRST
Researchers: Midshipmen 1/C Mark A. Obradovich and Teruo J. Toyama, USN
Adviser: Associate Professor Bradley E. Bishop

## Automated Windshield Wipers
Researchers: Midshipmen 1/C Laura K. Okruhlik and Carrie L. Suiter, USN
Adviser: Professor Thomas E. Bechert

## High Speed Scout Vehicle
Researcher: Midshipman 1/C Robert F. Richards, USN
Adviser: Assistant Professor Joel M. Esposito

## PC104 Microprocessor
Researcher: Midshipman 1/C Jonathan A. Shaver, USN
Adviser: Assistant Professor Joel M. Esposito

## Electrical Power Automation
Researcher: Midshipman 1/C Daniel S. Shevenell, USN
Adviser: Associate Professor Edwin L. Zivi

## Hover Car Network
Researchers: Midshipmen 1/C Nicholas E. Tsikalas, Grant A. Wanier and Gary J. Windt, USN
Advisers: Associate Professors Bradley E. Bishop, George E. Piper and Assistant Professor Matthew G. Feemster

## Inverted Pendulum
Researcher: Midshipman 1/C Serena N. Tyson, USN
Adviser: Associate Professor Richard T. O'Brien, Jr.

# Professional Publications

# Journal (Refereed) Manuscripts

BISHOP, Bradley E., Associate Professor, "Control of Platoons of Nonholonomic Vehicles Using Redundant Manipulator Analogs," *Proceedings of the American Society for Mechanical Engineers* (*ASME) Journal of Dynamic Systems, Measurements and Control, Special Issue on Novel Robots and Control,* March 2006, Vol. 128, No. 1, pp. 171 – 175.

> This paper considered the control of platoons of cooperating nonholonomic vehicles. Using techniques based on redundant manipulator control, the platoon was treated as a single entity with a set of platoon-level objectives. The class of tricycle-like robots with limits on steering and speed were chosen, as it represented a vast class of real, nonholonomic vehicles beyond the basic differential drive. The method presented used platoon redundancy to limit the impact of vehicle constraints on the platoon-level objectives. The technique was studied in simulations.

BISHOP, Bradley E., Associate Professor, CRABBE, F. I., Assistant Professor (Computer Science Department) and HUDOCK, B. M., (Trident Scholar 2003), "Design of a Low-Cost, Highly Mobile Urban Search and Rescue Robot," *Advanced Robotics*, September 2005, Vol. 19, No. 8, pp. 879 – 901.

> This paper discussed the design of a novel robotic platform for Urban Search and Rescue (USAR). The system developed possessed unique mobility capabilities based on a new adjustable compliance mechanism and overall locomotive morphology. The main facets of this work involved the morphological concepts, initial design and construction of a prototype vehicle, and a physical simulation which were used for developing controllers for semi-autonomous (supervisory) operation.

BISHOP, Bradley E., Associate Professor (co-author), "Redundant Manipulator Techniques for Partially Decentralized Path Planning and Control of a Platoon of Autonomous Vehicles," *Institute of Electrical and Electronics Engineers (IEEE) Transactions on Systems, Man and Cybernetics Part B*, August 2005, Vol. 35, No. 4, pp. 842 - 848.

> An approach to real-time trajectory generation for platoons of autonomous vehicles was developed from well-known control techniques for redundant robotic manipulators. The partially decentralized structure of this approach permitted each vehicle to independently compute its trajectory in real-time using only locally generated information and low-bandwidth feedback generated by a system exogenous to the platoon. Our work was motivated by applications for which communications bandwidth was severely limited, such as for platoons of autonomous underwater vehicles. The communication requirements for our trajectory generation approach were independent of the number of vehicles in the platoon, enabling platoons composed of a large number of vehicles to be coordinated despite limited communication bandwidth.

ESPOSITO, Joel M., Assistant Professor, FEEMSTER, Matthew G., Assistant Professor, and Watkins, John M., "Role of MATLAB® Real-Time Hardware Interface within a Systems Modeling Course," *American Society for Engineering Education* (*ASEE) Computers in Education Journal*, January 2006, Vol. 16, No.1, pp. 41-50.

> In an effort to offer students a more tangible understanding of system modeling concepts, the Quanser/MATLAB hardware interface was employed at USNA in the laboratory setting of an undergraduate modeling course. Specifically, the SIMULINK-based interface enabled students to model various physical systems and then compare the system performance predicted by their simulation to the actual response of the physical system. In this paper, an actual case study performed by the midshipmen utilizing the Quanser interface system with a rigid-link, flexible-joint robotic manipulator was presented.

O'BRIEN, Richard T., Jr., Associate Professor and KIRIAKIDIS, Kiriakos, Associate Professor, "Single-Snapshot Robust Direction Finding," *Institute of Electrical and Electronic Engineers (IEEE) Transactions on Signal Processing*, 2005, Vol. 53, No. 6, pp. 1964 - 1978.

This paper presented a novel approach for recursively estimating the directions of arrival of incident signals as measurements are received along a sensor array. Using a single snapshot and without any statistical assumptions, the proposed method employed a robust performance criterion, which was based on worst-case gain minimization. The criterion aimed to reduce the estimation error induced by worst-case amplitude and phase perturbations as well as additive noise in the array model. An algorithm that guaranteed the criterion---within a first-order approximation---was developed and shown to converge. Moreover, instead of using a trial-and-error method to find a constant, minimum worst-case gain, the minimum worst-case gain was updated as each sensor measurement was processed. A step-by-step implementation of the algorithm was presented and its computational complexity was analyzed. The performance of the new approach was evaluated by simulating the estimation algorithm for a linear array and comparing its performance to that of an existing single-snapshot algorithm.

PIPER, George E., Associate Professor, Watkins, John M., THORP, Owen G. Thorp, III, Captain, USNR, "Active Control of Axial-Flow Fan Noise Using Magnetic Bearings," *Journal of Vibration and Control*, Vol. 11, No. 9, 2005, pp. 1221-1232.

This paper presented a novel approach to reducing blade-rate noise of axial-flow fans. By using magnetic bearings as a noise control actuator, it was possible to collocate the anti-noise source with the disturbance noise source. This approach allows for global noise reduction throughout the sound field. A DC motor connected to a fan by a short rigid shaft was used to demonstrate this approach. The shaft was supported in the radial and axial directions by magnetic bearings. The bearings provided position control of the shaft and fan; this position control was used to vibrate the fan at a desired frequency and amplitude. Controlled vibration of the fan allowed its use as a speaker in an active noise control scheme. Noise control was implemented on a dedicated digital signal processor using a least mean square algorithm. The output of the noise control algorithm supplied the position commands for the magnetic bearing controller. Experimental data showed that by actuating the axial thrust bearing, the noise output of a fan could be reduced by 4 dB at the error microphone, and 3 dB at points away from the error microphone.

THORP, Owen G., III, Captain, USNR, Watkins, John M. and O'BRIEN, Richard T., Jr., Associate Professor, "Design and Implementation of Compensators in a Laboratory Environment for Engineering Students," *Computers in Education Journal,* September 2006, pp. 50-58.

This paper presented specific details about four labs in a Control Systems Design Laboratory course. The labs are Analog Compensator Design and Implementation for a Proportional-Integral (PI) Compensator, Analog Compensator Design and Implementation for a Proportional-Integral-Derivative (PID) Compensator, Digital Compensator Design for a Lead Compensator, and Digital Compensator Implementation for a Lead Compensator. These four labs represent the core of the Control Systems Design Laboratory Course and the culmination of the previous semester's theory into practice. The labs employ compensators which are well known to the students and demonstrate the processes of actual design and implementation, using both analog and digital methods, as well as some of the practical tools that can be employed in order to make the design process more efficient. The student feedback on all four of these labs continues to be positive.

ZIVI, Edwin L., Associate Professor, "Design of Robust Shipboard Power Automation Systems," *Annual Reviews in Control*, Vol. 29, No. 2, 2005, pp. 261-272.

Emergent power and automation technologies provide new opportunities and challenges for multidisciplinary ship design. In particular, these dynamically interdependent systems require dependable, fault tolerant control to efficiently manage limited resources and to respond to casualty conditions. Design

of an electric warship engineering and damage control system of systems was considered as an illustrative example. In this context, cost and survivability was considered as either deterministic or probabilistic independent variables. In the stochastic formulation, design robustness was defined with respect to uncertainties including technology readiness, mission creep and operational environment.

# Conference Proceedings

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor (co-author), "A Calibration Procedure for a Programmable Capacitance Standard," *Proceedings of the Conference on Precision Electromagnetic Measurements (CPEM) 2006*.

A programmable capacitance standard intended for use in an impedance measurement system is described. The standard provides capacitance values from 1 pF up to 10 ÿF with a resolution of 1 pF and consists of a parallel combination of commercially available capacitors with values that follow the Fibonacci series progression. This paper presents a novel calibration procedure for the programmable capacitor.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor (co-author), "Evaluation of Inductive Voltage Dividers and an 10 Nf Capacitors in a Capacitance Calibration Method," *Proceedings of the Conference on Precision Electromagnetic Measurements (CPEM) 2006*.

Researchers within the Quantum Electrical Metrology Division at the National Institute of Standards and Technology (NIST) implemented a calibration procedure for four-terminal-pair capacitance standards from 0.012 ÿF to 100 ÿF. This method depends on the accurate characterization of a 1 nF capacitor and an Inductive Voltage Divider (IVD) 1:10 ratio from 100 Hz to 100 kHz. This paper discussed a procedure that evaluates the IVD ratio and offers an enhancement over the current method. Also, the evaluation of the 10 nF capacitor was presented and a measurement procedure modification was suggested that significantly improved the results.

BISHOP, Bradley E., Associate Professor, "Dynamics-Based Control of Robot Swarms," *Proceedings of the 2006 Institute of Electrical and Electronic Engineers (IEEE) International Conference on Robotics and Automation,* Orlando, FL, May 2006. (CD-ROM)

In this work we considered methods for dynamics-based control of swarms of cooperating differentially-driven mobile robots. The techniques developed enabled the use of methods from redundant manipulator control and showed a marked improvement over equivalent kinematics-based techniques.

BISHOP, Bradley E., Associate Professor, WICK, Carl E., Professor and PIPER, George E., Associate Professor, "Teaching Robot Design: Student-Driven, Open-Ended Design Projects," *Proceedings of the 2006 American Society for Engineering Education ( ASEE) Conference and Exposition*, Chicago, IL, June 2006. (CD-ROM)

Robot design is a challenging topic to teach in a traditional course. Most approaches to instruction in the art of robot design focus on subsystem design followed by a common design project (typically involving a competition). While this method provided the students with experience in designing a robot to achieve certain objectives, there was often a distinct lack of rigor in the design process itself, with only success in the final competition as the metric by which the students evaluated their overall performance. Due to this 'goal-minded' behavior, students often resorted to *ad hoc* methods for design, losing sight of the principles of the discipline. To alleviate this problem, we provided students with an opportunity to develop their own design project and then carry it out as part of a course on mobile robot design. In this paper, we laid out the learning objectives and instructional strategies associated with this approach to design projects as well as student feedback on the project.

BROUSSARD, Randy P., Lieutenant Colonel, USAF, "A Stereo Vision-Based Wave Surface Measurement Project," *Proceedings of the 2006 American Society for Engineering Education (ASEE) Conference and Exposition*, Chicago, IL, June 2006. (CD-ROM)

> Measuring the three-dimensional characteristics of the ocean surface has a variety of applications. For example, surface measurements of vessel wakes could be used for improving hull designs. In the study of ocean surfaces, accurate surface measurements could be used for verifying ocean wave models or in lieu of such models in the study of various surface properties (i.e. microwave backscatter, etc.). We presented a vision-based wave sensing technique that can be used to measure water surface heights and compute pertinent wave characteristics, such as slope, height, or frequency. Using a commercially available stereo imaging system, students could acquire an image of a wave surface and accurately measure its characteristics. System configuration and data analysis methods were discussed. Data generated using this method was verified using traditional wave gauges, and used for a variety of student projects or laboratory experiments. We have used this system for a laboratory investigation in an Introduction to Computer Vision course, and as an experimental platform for independent study by Ocean Engineering students. Sample results from student projects in wave tank and natural water environments were presented.

ESPOSITO, Joel M., Assistant Professor and DUNBAR, T.W., (Trident Scholar 2005), "Wireless Constraints in Swarm Motion Planning", *Proceedings of the Institute of Electrical and Electronic Engineers* (*IEEE) International Conference on Robotics and Automation,* May 2006. (CD-ROM)

> The low power requirements of many small radio modems suggested that robust operation is best attained when the transmitter/receiver pair was: (1) separated by less than some maximum distance (Range); and (2) not obstructed by large dense objects (Line-of-Sight). Therefore to maintain a wireless link between two robots, it was desirable to comply with these two spatial constraints. Given a swarm of point robots with specified initial and final configurations and a set of desired communication links consistent with the above criteria, we explored the problem of designing inputs to achieve the final configuration while preserving the desired links for the duration of the motion. Some interesting conclusions about the feasibility of the problem were offered. An algorithm was provided and its operation was demonstrated through both simulation and experimentation on Koala Robots.

FEEMSTER, Matthew G., Assistant Professor (co-author), "Vision Assisted Autonomous Landing of an Unmanned Aerial Vehicle," *Proceedings of the Conference on Decision and Control*, Seville, Spain, December 2005, pp. 1465 – 1470.

> In this paper, a robust position tracking controller was developed for an autonomous, underactuated, unmanned underwater vehicle (UUV). Specifically, the proposed controller forces the three dimensional (*i.e.,* longitudinal, latitudinal, and depth) position tracking error to within an arbitrarily small region about zero (*i.e.*, global exponential uniformly ultimately bounded tracking) through the utilization of one translational and three orientation actuators. Therefore, the proposed methodology held special appeal to such underactuated applications as the omni-directional intelligent navigators (ODINs) by extending capabilities to include changes in vehicle depth. In addition, uncertainty in such parameters as vehicle inertia and hydrodynamic damping forces were compensated through a robust control structure. Simulation results were provided to illustrate performance and details of the controller.

FEEMSTER, Matthew G., Assistant Professor, ESPOSITO, Joel M., Assistant Professor and NICHOLSON, John W., Captain, USN, "Manipulation of Large Objects by Swarms of Autonomous Marine Vehicles: Part I - Rotation", *Proceedings of the Institute for Electrical and Electronic Engineers (IEEE) Southeastern Symposium on Systems Theory*, Cookeville, TN, March 2006, pp. 255-259.

> In this paper we considered the problem of a team of autonomous marine vehicles (i.e. tug boats) cooperating to manipulate a larger floating object (i.e. disabled ship). After decomposing the problem into several phases, we presented a formal problem statement focusing on the issue of inducing controlled

rotations for the manipulated object. A redundant control methodology was introduced and demonstrated in simulation. We analyzed the implications of relaxing some of the initial assumptions (unknown model parameters, etc.). In the final section we report on the development of an experimental platform.

KIRIAKIDIS, Kiriakos, Associate Professor, "Mixed Mathematical and Physical Modeling for Nonlinear Systems," *Proceedings of the American Society for Mechanical Engineers (ASME) International Mechanical Engineering Congress and Exposition*, Orlando, FL, November 2005, CD-ROM.

The paper proposed a finite series expansion to approximate general nonlinear dynamic models to arbitrary accuracy. The method produced an approximation of nonlinear dynamics in the form of an aggregation of linear models, weighted by unimodal basis functions, and resulted in a linear growth bound on the approximation error. Furthermore, the paper demonstrated that the proposed approximation satisfies the modeling assumptions for analysis based on linear matrix inequalities and hence widens the applicability of these techniques to the area of nonlinear control.

KIRIAKIDIS, Kiriakos, Associate Professor and O'BRIEN, Richard T., Jr., Associate Professor, "A Comparison of H-infinity with Kalman Filtering in Parameter Identification," *Proceedings of the American Society for Mechanical Engineers (ASME) International Mechanical Engineering Congress and Exposition*, Orlando, FL, November 2005, CD-ROM.

The authors performed a thorough investigation of the extended H-infinity and Kalman filters based on results from stiffness estimation experiments. The paper used the time-varying tolerance method to tune the H-infinity filter. Exploring similarities in the associated Riccati equations, the authors also proposed a new approach for tuning the Kalman filter. The experimental results show that the H-infinity outperforms the Kalman filter along a wide range of tuning parameter values.

KIRIAKIDIS, Kiriakos, Associate Professor and O'BRIEN, Richard T., Jr., Associate Professor "On H-infinity Based Direction Finding and Source Detection," *Proceedings of the 13th European Signal Processing Conference*, Antalya, Turkey, September 2005, CD-ROM.

Recently, the authors have proposed a novel approach to Direction-Of-Arrival (DOA) estimation using the H-infinity criterion. This article examined the limits of performance of H-infinity-based direction finding and arrives at a lower bound on the estimation error, analogous to the Cramer-Rao Bound (CRB). Furthermore, the analysis of the H-infinity-based algorithm's prediction error using one of Akaike's information criteria shows that the direction finding algorithm at hand possesses source detection ability.

O'BRIEN Richard T., Jr., Associate Professor, "Bang-Bang Control for Type-2 Systems," *Proceedings of the 38$^{th}$ Institute of Electrical and Electronic Engineers ( IEEE) Southeastern Symposium on Systems Theory*, Cookeville, TN, March 2006, pp. 163-166.

A sampled-data, bang-bang control algorithm developed for a double integrator plant was extended to higher-order plants with two integrators. In the case where non-integrator dynamics were considered unmodeled, the robustness of the control algorithm was analyzed. In the case where non-integrator dynamics are modeled, the control algorithm design procedure is generalized to incorporate the additional dynamics. Both approaches are examined through the design and simulation of a steering controller for an autonomous ground vehicle.

O'BRIEN Jr., Richard T., Jr., Associate Professor and KIRIAKIDIS, Kiriakos, Associate Professor, "A Comparison of H-infinity with Kalman Filtering in Vehicle State and Parameter Identification," *Proceedings of American Control Conference*, Minneapolis, MN, June 2006. (CD-ROM)

> The Kalman and H-infinity filters, which aim to minimize separate criteria, were optimal only in ideal circumstances. A question that arose in practice was how to determine which filter performs better using a posterior common criterion pertinent to the application. To address this issue, the authors used the mean squared error as a measure of performance while ensuring that the filters' tuning parameters were also comparable. Analysis of combined state variable and parameter estimation, in the area of vehicle dynamics, has shown that the H-infinity filter has the ability to outperform the Kalman filter as long as the respective Riccati equations start from the same initial condition.

PIPER, George E., Associate Professor (co-author), "Study of Pointing Maneuvers for a Spacecraft Virtual Structure Formation," *Proceedings of the 38th Institute of Electrical and Electronic Engineers (IEEE) Southeastern Symposium on System Theory,* Cookeville, TN, March 2006. (CD-ROM)

> This paper described a complex virtual simulation of three spacecraft in tight formation. Using rotational kinematics and rigid body dynamics, the virtual spacecraft structure was designed to perform calculated and synchronized maneuvers to point the formation in a desired direction. Modern control theories were applied to maintain the integrity of the tight formation and minimize errors as the entire system reorients to tracks the target object with its virtual boresight. This process involved determining the required independent orientation (Eulerian) angles using the target vector coordinated with respect to the initial orientation of the formation.

REED, Caleb M., (Trident Scholar 2006), BISHOP, Bradley E., Associate Professor and WATERS, Jennifer K., Associate Professor, (Naval Architecture and Ocean Engineering Department), "Hardware Selection and Modeling for a Small Autonomous Surface Vessel," *Proceedings of the 38th Institute of Electrical and Electronic Engineers (IEEE) Southeastern Symposium on Systems Theory,* March 2006, pp. 196 - 200.

> This paper focused on the process of selecting hardware for use in the design of a small autonomous surface vessel design. Hull form, powering and instrumentation were discussed, with hardware specifications and performance data. Existing mathematical models appropriate for the vessel were outlined and a discussion of model identification using traditional and *in situ* methods was presented.

REED, Caleb M., (Trident Scholar 2006), BISHOP, Bradley E., Associate Professor and WATERS, Jennifer K., Associate Professor, (Naval Architecture and Ocean Engineering Department), "Design of an Autonomous Surface Vessel," *Proceedings of the 2006 World Maritime Technology Conference*, London, UK, March 2006, CD-ROM.

> In this work, we discussed the motivation for and development of a small (81cm) autonomous surface vessel (ASV). Details of the final platform were discussed, including vessel specifications, actuation design, instrumentation and on-board control. The vessel will be used for studies on small ASVs in littoral zones, including navigation and control.

TYSON, Serena N., Midshipman 1/C, USN, O'BRIEN, Richard T., Jr., Associate Professor, and FEEMSTER, Matthew G., Assistant Professor, "An Investigation of a Robust Swing-Up Control Design for a Rotary Inverted Pendulum," *Proceedings of the National Conference on Undergraduate Research*, Asheville, NC, April 2006. (CD-ROM)

> In this paper, a comprehensive study of the swing-up controller design for a rotary inverted pendulum was considered. Specifically, the scope of this paper was the evaluation of an energy based swing-up control strategy on a common experimental platform in an effort to determine performance and robustness characteristics with respect to parameter and model uncertainty. Results from this investigation will serve

as a foundation from which further research will be conducted into the development of a robust swing-up control strategy.

# Technical Reports

O'BRIEN, Richard T., Jr., Associate Professor and KIRIAKIDIS, Kiriakos, Associate Professor, "An H-Infinity-based Detection and Tracking Method for Underwater Sensor Systems," Office of Naval Research End-of-the-Year Report, September 2005.

The long-term goal for the project was to develop a robust algorithm for the detection and tracking of moving targets in the near field using a single snapshot of measurements from an array of sensors with arbitrary geometry. There were three goals for the algorithm development. First, the algorithm was adaptable to different sensors, array geometries, and sources (narrow-band and broad-band). Second, the algorithm maintained an acceptable performance level in the presence of unmodeled phenomena (*e.g.,* scattering at the source) and measurement noise. Third, the algorithm was computationally efficient and amenable to local processing at each sensor. In FY05, we pursued the following objectives: 1) developed an appropriate state-space form of the array model so that $H_\infty$-based estimates of the signal's parameters are real-valued although the signal itself is complex-valued, 2) tested and verified the $H_\infty$-based detection and localization results using the synthetic data, and 3) compared the algorithm's performance with baseline methods.