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2011 Annual Report of the Graduate School of Engineering and Management, Air Force Institute of Technology

Office of Research and Sponsored Programs, Graduate School of Engineering and Management, AFIT

AIR FORCE INSTITUTE OF TECHNOLOGY

AIR FORCE INSTITUTE OF TECHNOLOGY
GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT

Annual Report

2011

Official Publication of the Air Force Institute of Technology

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Public Affairs Officer	Bill Hancock
Editorial and Design	Lori Ann Kinder

Editorial Office:
AFIT/ENR
2950 Hobson Way
WPAFB, OH 45433-7765
Telephone: 937. 255-3633
Fax: 937.656.7139
Email: research@afit.edu

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2011 A Year In Review

JANUARY
AFIT exhibits at AETC Training and Education Symposium.

FEBRUARY
AFIT Alum Steve W. Lindsey commands final flight of Discovery and 133rd flight of the Space Shuttle Program.

DECEMBER
Five AFIT faculty members were recognized as an Excellence in Education Honoree in Ohio Magazine.

NOVEMBER
AFIT hosts Sir John Pendry for AFOSR Seminar Series.

OCTOBER
CCR Cyber 200/300 Professional Continuing Education Team received the Government Information Security Leadership Award for demonstrated leadership in advancing and improving the information security workforce.

MARCH
Gen Donald J. Hoffman gives commencement address to 230 AFIT graduates.

APRIL
AFIT hosts Air University's Board of Visitors.

MAY
First cohort begins MS in Cost Estimating and Analysis program jointly developed and instructed by AFIT and NPS.

JUNE
Gen Edward A. Rice visits AFIT.

JULY
AFIT hosts Secretary of the Air Force, Mr. Michael B. Donley.

AUGUST
AFIT's first International Cooperative Research and Development Agreement with Kwangwoon University (Seoul) and University of Toledo signed.

SEPTEMBER
AFIT and WSU sponsor CBRNE research and education symposium.

Message from the Dean

The Air Force Institute of Technology's (AFIT's) longstanding commitment to excellence in research-based graduate education provides an outstanding return on investment to the Air Force and Department of Defense (DOD). Our graduates apply their enhanced skills throughout their military and civilian careers; our research sponsors leverage our faculty's expertise to obtain low-cost, high-quality technical results; and the Air Force relies on our capabilities to quickly address emerging educational requirements. This Annual Report highlights a few of AFIT's many contributions during the past year.

During FY11, the Graduate School awarded 344 master's and 30 PhD degrees in technical disciplines critical to addressing today's challenges. Over 85% of these students conducted research directly sponsored by organizations external to AFIT, such as the Air Force Research Laboratory (AFRL), including the Air Force Office of Scientific Research (AFOSR); National Security Agency (NSA); National Science Foundation (NSF); High Energy Laser Joint Technology Office (HEL-JTO); Defense Threat Reduction Agency (DTRA); and National Air and Space Intelligence Center (NASIC). Our sponsors provided a record $22 million in support, indicating satisfaction with their previous investments at AFIT.

The Carnegie Foundation identified AFIT as a doctoral/research institution for the first time in FY11, in recognition of our doctoral education productivity with strong research activity in Science, Technology, Engineering, and Mathematics (STEM) disciplines.

AFIT's research and educational objectives are strongly aligned with the Air Force's and DOD's strategic and technical priorities, as outlined in CSAF Vector 2011, Air Force Science and Technology Strategy 2010, and OSD's Science and Technology Priorities for Fiscal Years 2013-2017 Planning. This Annual Report's feature articles on the Center for Cyberspace Research (CCR) and Center for Technical Intelligence Studies and Research (CTISR) illustrate the relevance of our programs. CCR faculty members and students are developing advanced cyber-related theories and technologies to improve network intrusion detection and avoidance, mitigate insider threats, and develop anti-tamper technologies. CTISR researchers are creating new methods to derive information from remote sensing data, developing virtual learning environments, and pioneering human activity characterization techniques. AFIT's research efforts result in products that transition to the battlefield and support the current fight in the near term, while advancing toward breakthrough capabilities.

AFIT's graduates, students, faculty, and staff are very proud of our long and distinguished history of educational and research accomplishments in support of the Air Force mission. Looking to the future, I have no doubt that AFIT will continue to meet the nation's technical challenges with valuable research innovations and high-quality, defense-focused educational programs.

Respectfully,
M. U. Thomas, PhD, PE
Dean, Graduate School of Engineering and Management

CENTER FOR TECHNICAL INTELLIGENCE STUDIES AND RESEARCH

Building Teams That Address the Intelligence, Surveillance, and Reconnaissance Community's Technology

The Center for Technical Intelligence Studies and Research (CTISR) arose out of the recognition in the late 1990s that the Intelligence Community (IC) was in dire need of additional scientists and engineers with MASINT (Measurement and Signature Intelligence) expertise. Discussions with the Central MASINT Office (CMO) led to the creation of the Center for MASINT Studies and Research in 2001, with Dr. Ronald Tuttle as the founding Center Director. Since that time, the Center's scope has evolved, and the IC functionally reorganized MASINT into traditional MASINT and advanced Geospatial Intelligence (GEOINT). To reflect these changes, the name of the Center was changed in 2011.

Through focused education initiatives, high-quality research that addresses critical technical deficiencies, and a deep understanding of the technical IC, the CTISR strives to advance the state of technology and technical expertise within the Air Force, DOD, and IC.

MISSION STATEMENT:
Provide a cadre of technical intelligence graduates by conducting graduate-level research and education in collaboration with government organizations and the private sector.

VISION:
To be recognized by the DOD and the IC as a strategic resource for technical intelligence research and a key academic partner for educating technical intelligence professionals in the 21st century.

Research Impacts through Collaborative Partnerships

The CTISR has an active, interdisciplinary research portfolio that addresses IC and DOD technical intelligence requirements and works collaboratively with military, academic, industrial, and IC organizations. CTISR has established teaming arrangements both within AFIT and with external and federal organizations, such as the National Air and Space Intelligence Center (NASIC); National Reconnaissance Office (NRO); National Security Agency (NSA); Defense Intelligence Agency (DIA); Army Research Laboratory (ARL); Air Force Research Laboratory; and academic institutions, such as the Naval Postgraduate School (NPS), Wright State University, Virginia Polytechnic Institute and State University, New Mexico State University, University of Missouri, and Utah State University. Since 2004, 14 such partnerships have resulted in teams able to address unique intelligence needs that no single entity could address without appreciable IC financial investment. Funding has exceeded over $4.5 million during the previous five years to address difficult problems related to ISR, including adversary intent determination, persistent surveillance, hard target requirements, denial and deception, and force protection.

Transforming IC Education

Compounded by the requirement for high security clearances and the closed and compartmentalized nature and unique demands of the IC, the CTISR addressed workforce development needs by developing the Advanced Geospatial Intelligence (AGI) Certificate Program (ACP). The ACP provides a coherent development of the science and applications of AGI Infrared and Synthetic Aperture Radar. Since 2002, the ACP has had 32 offerings, 417 enrolled students, and over 200 awarded certificates. The program is jointly funded by the National Geospatial-Intelligence Agency (NGA) and Air Force and is now integrated into the NGA AGI education and training track.

Since its formation in 2001, the Center has become a national resource for the technical IC for researching and educating a new generation of GEOINT and MASINT professionals. Under its new name, the CTISR will continue to contribute to the preeminence of our air, space, ground, naval, and cyberspace forces.

CTISR Research Areas

- Remote Sensing Collection Algorithm, Sensors, and Systems
- Signature Phenomenologies
- Indigenous Sensors
- Wide Area Persistent Surveillance
- Atmospheric Propagation
- Virtual Learning Environments
- Human Activity Characterization/Advanced Biometrics

Contact: Dr. Ronald Tuttle
937.255.3636 x4536
ronald.tuttle@afit.edu

For more information, visit www.afit.edu/en/ctisr/.

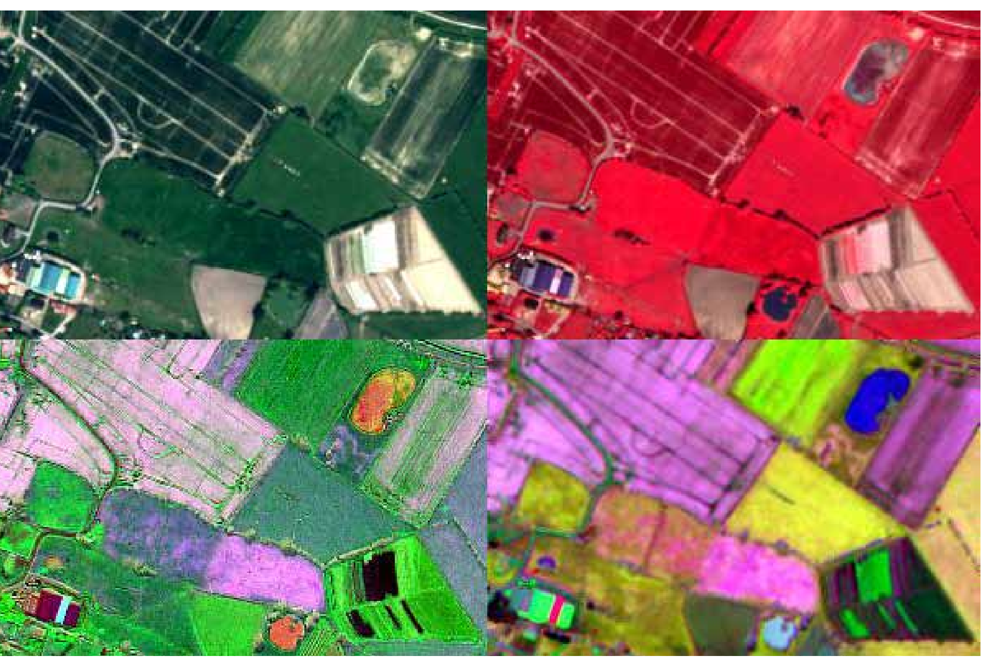
CTISR Faculty and Staff: (top left) Lt Col Karl Walli, Dr. Christoph Borel-Donohue, Don Hemminger, Erica Arnett, Dr. David Bunker; (bottom left) Dr. Amy Magnus, Jennifer Vanzant, and Dr. Ronald Tuttle (Director, CTISR)

Research Professor Wins DigitalGlobe International Competition with Vegetative Mapping

Mapping vegetation parameters can provide important information about an adversary's ability to hide targets of interest, such as vehicles and tanks. Dr. Christoph Borel-Donohue's award winning research paper, "Vegetative canopy parameter retrieval using 8-band data," contributes to disaster assessment, precision agriculture, forestry, and environmental remote sensing by providing an algorithm that efficiently creates maps of key vegetation parameters, using data from DigitalGlobe's WorldView-2 (WV-2) satellite sensor.

The WV-2 satellite sensor orbits the Earth every 90 minutes at a distance of 770 km and has 8 spectral bands that are uniquely suited to these vegetation mapping applications. Until now, commercial high-resolution images from other sensors, such as Ikonos and Quickbird, used four bands that could estimate only the leaf area index. At the fine spatial resolution of 0.5 m (panchromatic) and 2 m (multispectral) of WV-2, individual trees can be readily resolved. Dr. Borel-Donohue's new algorithm can also be used to facilitate mapping of anticipated changes of vegetation cover and type with global change. Figure 1 shows examples of retrieved vegetation parameters from related algorithms developed by Dr. Borel-Donohue.

Dr. Borel-Donohue received one of five awards in an international competition sponsored by DigitalGlobe. The competition drew interest from over 500 researchers from 79 countries with only one other winning entry from the United States.



Left: Sub-image showing a true color composite (upper left), false color composite (upper right), pseudo color with red=Chlorophyll content, green=Leaf area index, blue=Average leaf angle (lower left) and pseudo color with red=Leaf area index, green=Structure coefficient, blue=Brown pigment (lower right). This image shows how different vegetation types can be distinguished using the false color images of the vegetation maps. A magenta colored path crossing the grassy area in the lower left center area is clearly visible in the lower right image, showing that small differences in leaf area index and structure parameters can reveal subtle features. (Photo made available by DigitalGlobe)

Contact: Dr. Christoph Borel-Donohue
937.255.3636 x4957
christoph.borel-donohue@afit.edu

Sensing Concepts for Understanding Human Activity in Assembly

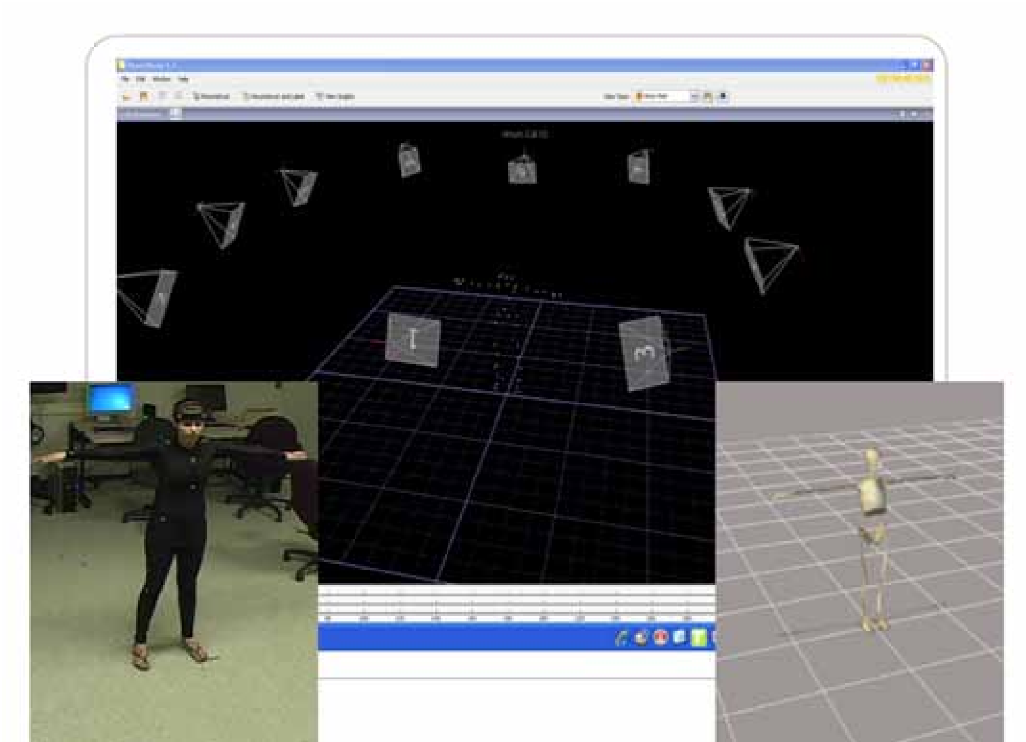
AFIT researchers are building upon recent successes in modeling the human walk (i.e., gait analysis) to develop more extensive models of human activities. Led by Dr. Amy Magnus, Video Analysis and Content Extraction (VACE) laboratory researchers are investigating sensing concepts that enable multimodal 4D modeling of human activity, such as the assembly of improvised explosive devices (IEDs).

Human activities tend to be dominated by either the body's lower or upper extremities. In their anthropometric studies of gait, VACE laboratory researchers have explored the natural flow of the head, shoulder, elbow, wrist, knee, and foot in running, walking, and climbing. New analyses of assembly activities concentrate on the movements of the upper extremities: the head, wrist, elbow, and shoulder.

In the laboratory's investigation, a human activity is broken into an abstraction of starts, stops, splits, and joins. Defense Advanced Research Projects Agency (DARPA) investigators have applied this abstraction to the Video and Image Retrieval and Analysis Tool, which is an advanced search engine for discovering human activity in full motion video. Researchers from the University of Rochester have fleshed out a temporal logic for starts and stops. VACE researchers are applying this temporal logic to the AFIT study and articulating a supplemental logic for splits and joins in a multidisciplinary effort joined by University of Rochester computer scientists, Rome Research Site information extraction experts, and a Central State University mathematician.

Scenarios have been selected to fit within the confines of the VACE laboratory, as depicted below. Initial VACE studies will analyze cooking activities due to its parallels to IED assembly in terms of scale and complexity, as well as cooking's interesting complication from varying thermal signatures. Based on early results, AFIT researchers postulate that enhanced sensing concepts are within reach that not only detect particular human activity but authoritatively assess the threat that particular activities represent.

Contact: Dr. Amy Magnus
937.255.3636 x4555
amy.magnus@afit.edu



Left: A subject stands for calibration purposes within the VACE laboratory. The subject's body is detected via a Vicon Motion Capture System. A skeletal model of the subject is generated from the Vicon data from which joint placement and dynamics can be assessed.

Immersive Online Learning: New Virtual Radar Lab

The CTISR has produced the AFIT Virtual Radar Lab (VRL), a fully interactive, immersive online learning environment that replicates the learning experience a student would encounter in a real physical radar lab, without the need for costly travel or the purchase and maintenance of expensive lab space and equipment.

VRL is a proof-of-concept course developed as part of CTISR's Virtual Graduate Laboratory Environment (VirGLE) project. The VirGLE project is intended to provide better and more effective learning experiences for current and future students anytime, anywhere, on their own schedule, while also taking into account the unique capabilities and perspectives of the "Millennial Generation." VirGLE will provide a general development framework for applying technology based solutions using sound instructional design techniques, so other interested educators and organizations have a model for quickly producing their own effective immersive learning environments.

The AFIT VRL can be accessed via the Internet with any commonly used browser. While in the VRL, students can fully explore the environment at their own pace and in their preferred learning style. Students can perform all the necessary functions on the virtual LabVolt® system in much the same way they would in the physical lab, including selecting and connecting cables; adjusting knobs and pushing buttons to modify component settings; controlling the movement of the target table; programming the movements of the antenna; and calibrating the (realistic) display on the Oscilloscope.

The VRL models the lab environment at a number of different levels to provide a very robust, realistic, and educational experience for its users. It closely models the physical environment of the lab, including the room, all the necessary equipment, and participating characters (first-person user and an avatar-based lab assistant), but this is only the beginning. To realize the full benefit of this pedagogical approach requires accurate modeling of the electronic operation of the LabVolt® equipment; the set of possible interactions that are available to the user; effective and effortless navigation around the environment; and, most importantly, instructional details and methodologies of the experience.

The VRL is just one example of the kind of structured educational experience that can be created with the innovative application of new and emerging technological capabilities being explored under the VirGLE project. Future possibilities include the continuing evolution of 3D game-based environments and integration of highly networked portable devices with capabilities like GPS and gyroscopic movements and gestures.

Contact: Dr. Ronald Tuttle
937.255.3636 x4536
ronald.tuttle@afit.edu

Remote Sensing Technology Aids Pollution Monitoring

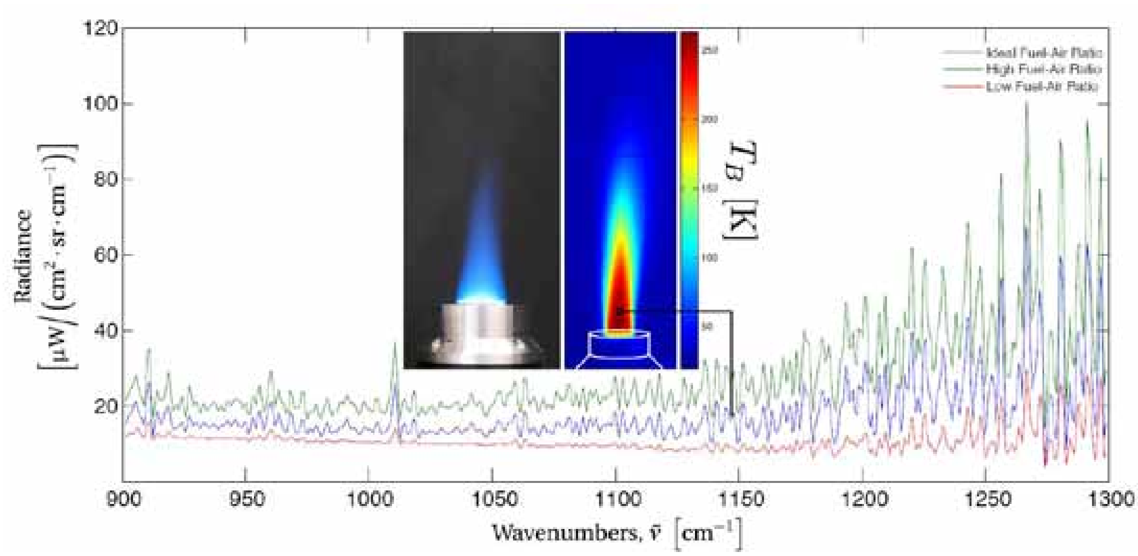
Imaging Fourier-transform spectrometry (IFTS) has recently become commercially available, and AFIT's Remote Sensing Group is developing methods to use this technology for remote combustion diagnostics and pollution monitoring.

The petrochemical industry routinely employs open-air flares to dispose of combustible waste gases. Under ideal conditions, all carbon and hydrogen in the waste are converted to carbon dioxide and water. However, when the combustion is incomplete, particulate material and ozone-producing volatile organic compounds (VOCs) can be released into the atmosphere, posing health and environmental risks. Since most flaring operations lack in situ combustion efficiency (CE) diagnostics, methods for remotely monitoring CE are needed, as the cost of retrofitting flares is prohibitive. Current methods of CE estimation—extractive point sampling, open-path FTIR, and differential absorption LIDAR—are accurate yet cumbersome, impractical tools for monitoring a large number of flares. Instead, industry and environmental agencies both desire a "point-and-shoot" system for flare CE monitoring, and AFIT technology and expertise may be able to help.

IFTS combines a Michelson interferometer with an infrared focal-plane array, so a spectrum can be acquired at every pixel in a 2D image. Recent master's and PhD work at AFIT produced IFTS techniques for quantifying mass flow rates of pollutants from industrial smokestacks. Leveraging these methods, we are currently developing IFTS for flare CE measurements and broadening our expertise in combustion remote sensing.

AFIT has partnered with Spectral Sciences and the University of Utah to develop a system for the real-time monitoring of CE and VOCs in industrial flares. Spectral Sciences is developing the radiative transfer models necessary to simulate infrared flare plume spectra. The University of Utah team is applying their state-of-the-art computational fluid dynamic (CFD) and chemical reaction models to predict the flow-field state, including temperature, density, and species concentrations throughout the flare plume. Spectral Sciences sought out AFIT as a team member because of our cutting-edge IFTS instrumentation and modern laboratory facilities. AFIT is standing up a laboratory scale flare testing facility to capture temporally and spatially resolved infrared spectra to validate and improve the reactive flow CFD and radiative transfer models.

Contact: Dr. Kevin Gross
937.255.3636 x4558
kevin.gross@afit.edu



Right: Single-pixel, infrared propane flame spectra corresponding to three different fuel-air ratios. A visible image of the flame under ideal fuel-air ratio is presented alongside a brightness temperature map at 1267 cm^{-1}. A radiative transfer model being developed will enable gas kinetic temperatures and combustion by-product concentrations to be retrieved from each spectrum.

CENTER FOR CYBERSPACE RESEARCH

The Center for Cyberspace Research (CCR), established in March 2002, conducts defense-focused research at the master's and PhD levels. In 2008, the Secretary and Chief of Staff of the Air Force designated AFIT and CCR as the Air Force's Cyberspace Technical Center of Excellence (CyTCoE). The CyTCoE is chartered to be a unifying and synergistic body for promoting cyberspace education, training, research, and technology development. The CyTCoE facilitates the development of Air Force education and training in support of cyber operations and identifies and provides subject matter experts that understand doctrine, techniques, and technology to ensure dominance and superiority in cyberspace.

The Air Force designation builds on a long history of AFIT's efforts in cyber defense. As a nationally recognized focal point for cyberspace advancements in education, research, and consultations, CCR is focused on the changing needs of the Air Force, DOD, and Federal Government. CCR's outstanding reputation earned a designation from the National Security Agency (NSA) and Department of Homeland Security (DHS) as a Research Center of Excellence and Center of Academic Excellence in Information Assurance Education, which demonstrates AFIT's commitment to meet exceptional research and educational standards.

As the CyTCoE, CCR will serve as a bridge between the operational Air Force cyber forces and various cyber research, education, and training communities across the Air Force, DOD, and national organizations. Leadership from a Distinguished Review Board and Board of Advisors comprised of Air Force and DOD senior leaders provides oversight and direction for the Center.

To meet the nation's growing demand for a workforce trained to fill jobs in cyber defense, CCR provides a full spectrum of cyber education that ranges from the Cyber 200/300

CCR Distinguished Review Board

professional continuing education courses to the master's and PhD levels with degrees awarded through AFIT's Department of Electrical and Computer Engineering. Graduate students perform research that develops advanced cyber-related theories, techniques, and technologies. In addition to cyber education for AFIT's traditional military students, opportunities are also available for non-military students seeking a master's degree in cyber operations through the National Science Foundation's (NSF's) Scholarship for Service program (CyberCorps). Upon degree completion, CyberCorps students work in a cyber security related position for a DOD or other United States Government agency.

MISSION STATEMENT:

Developing the cyber warrior through education and research.

VISION:

Enable the Air Force and DOD to dominate cyberspace at will while denying our adversaries the ability to do the same.

Defense-focused research is a key mission component and is central to graduate education at AFIT. With the synergistic advantages of faculty members with extensive military operational experience and close working relationships with DOD and Air Force organizations, CCR promotes an environment for collaborative research that solves real-world communications and security issues facing our nation. Some of the ongoing research efforts include:

- Critical infrastructure protection and exploitation
- Cyber risk assessments/analysis
- Cyberspace command and control
- Digital forensics and software protection
- Hardware and software protection and exploitation
- Insider threat detection and mitigation
- Malicious code detection and analysis
- Radio frequency identification
- Space asset vulnerabilities
- Wireless network security

Contact: Dr. Richard Raines
937.255.3636 x4278
richard.raines@afit.edu

For more information, visit www.afit.edu/en/ccr/.

Finding Data Leaks in Cryptographic Devices and Detecting Cloned Smart Cards with Side Channel Analysis

Electronic devices leak information about the algorithms and data they process through side channels. Side channels can come in the form of a device's measured power consumption over time; minute differences in the amount of time required for the system to process different data; radio frequencies unintentionally emitted by the device; etc. The information leakage of electronic devices, especially those used in cryptographic applications or other vital system functions, represents a serious practical threat to secure systems. Adversaries can use side channel attacks to exploit weaknesses in the physical implementations of the cryptographic algorithms that protect sensitive or classified information. While physical implementation attacks have evolved rapidly over the last decade, relatively little work has been done to allow system designers to effectively detect and counter information leakage threats.

CCR has developed state-of-the-art techniques to assess and counter these side channel attacks. One technique, known as leakage mapping, comprehensively measures the vulnerability of a system to a variety of side channel attacks. It is the first known technique that gives a complete picture of information leakage risks and provides an assessment of mitigation strategies that can be used to protect electronic systems and their data.

Another process developed by CCR, radio frequency distinct native attribute (RF-DNA) fingerprinting, exploits nanoscale differences inherent in microchip manufacturing to uniquely identify the chips in a manner analogous to biometric human cost and scalability advantages over existing approaches.

AFIT currently has patents pending for both their leakage mapping and RF-DNA device fingerprinting processes. This research has contributed directly to the U.S. military's capability to develop and maintain a strong technology base and prevent, deter, or delay the exploitation of secure communications equipment, remote sensing platforms, and a variety of other in-theater critical systems. Protecting our intellectual property also increases opportunities for the safe export of these technologies and extends the effective operational life of U.S. weapons systems.

Software Protection Technology

Enhanced Signed Code Application for Page-level Execution (ESCAPE) is a patent-pending technology developed at CCR by Mr. Bill Kimball. ESCAPE technology leverages non-executable page-level permissions to control instruction execution by only marking a page executable if the dynamically computed cryptographic signature of the page, after being loaded, is identical to a stored signature.

ESCAPE protects a system from a wide range of attack vectors, including social engineering, command injection, heap spraying exploits, and stack overflow exploits, by focusing on proactively preventing the execution of a cyber attacker's payloads independent of how the malicious instructions are placed onto the machine. The technology is suitable for any computer system using processors that support modern memory paging technology. Thus, virtually all commercial computers and operating systems (general purpose and embedded) and many cellular phones and other mobile devices can incorporate the technology.

Pages 12 & 13 Contact: Dr. Rusty Baldwin
937.255.3636 x4445
rusty.baldwin@afit.edu

Malware Target Recognition Outperforms Competitors

Organizations increasingly rely on the confidentiality, integrity, and availability of their information and communications technologies to conduct effective business operations while maintaining their competitive edge. Exploitation of these networks via the introduction of undetected malicious software (known as malware) ultimately degrades their competitive edge while taking advantage of limited network visibility and the high cost of analyzing a massive number of programs.

Department of Electrical and Computer Engineering faculty members and graduate, Maj Thomas Dube, researched the novel Malware Target Recognition (MaTR) system, which combines the decision tree machine learning algorithm with static heuristic features for malware detection. By focusing on contextually important static heuristic features, this research demonstrates superior detection results. Experimental results on large sample datasets demonstrate near ideal malware detection performance (99.9+ accuracy) with low false positive and false negative rates at the same point on the performance curve. Test results against a set of publicly unknown malware, including potential advanced competitor tools, show MaTR's superior detection rate of 99% versus the union of detections from three commercial antivirus products at 60%. The resulting model is a fine granularity sensor with potential to dramatically augment cyberspace situation awareness.

MaTR shows great promise for detecting advanced, competitive threat tools or malware. By effectively detecting malware on DOD networked computer systems used for daily operations, such as email, financial transactions, logistics, and dissemination of sensitive information, MaTR would ultimately reduce exposure to harm for United States military members and our allies as adversaries have reduced visibility into daily operations.

Maj Dube's research effort was published in the Journal of Computers and Security and awarded Best Paper at the IEEE International Symposium on Social Computing in Minneapolis, Minnesota.

Engineering Mission Assurance in Critical Infrastructure Control Systems

Mission assurance enables government agencies to integrate security continuity and risk management practices to develop a day-to-day operational model that safeguards employees and the business. This same philosophy can be applied to DOD Supervisory Control and Data Acquisition (SCADA) networks through the careful integration of risk management and information assurance (IA) controls to achieve mission assurance objectives.

CCR researchers interviewed USAF Civil Engineering subject matter experts representing eight Major Commands that manage and operate SCADA systems across the USAF enterprise. They ranked 30 IA controls in three categories and evaluated eight SCADA-specific IA controls to include in the DOD IA control framework managed by the Assistant Secretary of Defense for Networks and Information Integration. There was a high preference for system and information integrity and encryption as key IA controls to mitigate cyber risk. Equally interesting was the strong agreement among raters on ranking certification and accreditation dead last as an effective IA control.

These results are valuable to the Air Force Civil Engineer Support Agency (AFCESA) as they continue to look for innovative ways to reduce the attack surface of USAF control systems. This research was part of a multi-year Critical Infrastructure Protection project sponsored by HQ USAF A4/7.

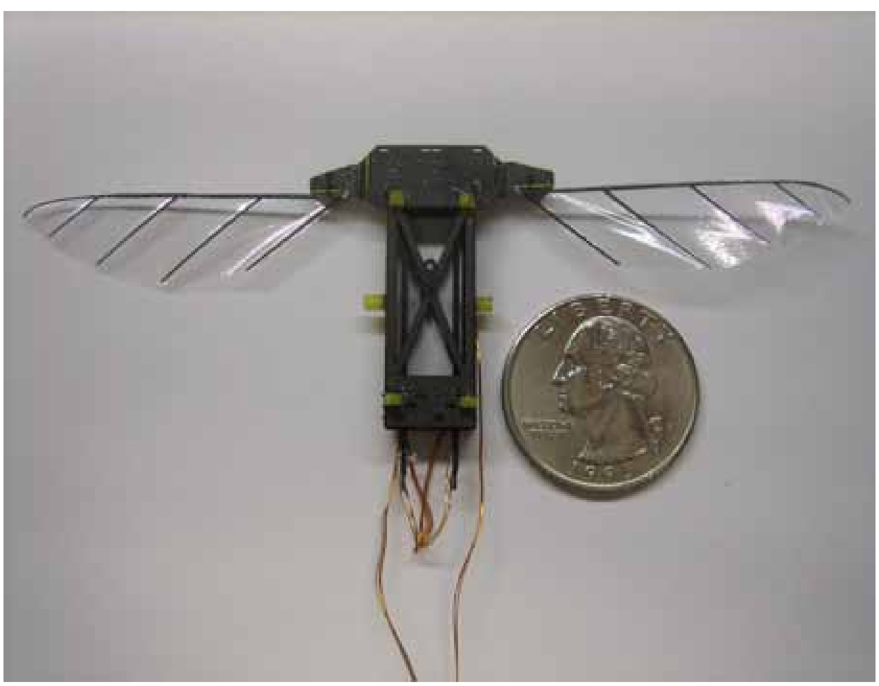
Bio-Inspired Micro Air Vehicles

Unoccupied Air Vehicles (UAVs) have become pervasive in modern warfare by providing real-time intelligence, surveillance, and reconnaissance (ISR) to the warfighter without the limitations and massive logistics footprint of manned flight. Recently, Micro Air Vehicles (MAVs) have been proposed to provide a similar capability but in a drastically smaller package.

A team of AFIT researchers is investigating all aspects of flapping wing control of MAVs by studying their biological counterparts and replicating their behavior on laboratory micro-machined prototypes.

MAVs are autonomous vehicles with a maximum dimension of 15 cm or less and weighing 90 g or less. They can easily be carried by small combat units and flown in confined spaces, such as urban canyons, caves, and indoors. MAVs of many shapes and sizes have been proposed, but most have either fixed, rotary, or flapping wings. Flapping wing MAVs (FWMAVs) have several advantages over fixed and rotary wing vehicles. They capitalize on several unsteady aerodynamic effects that generate additional lift at the low Reynolds numbers experienced by vehicles of this size; they have superior maneuverability, including the ability to hover; and they mimic biological flyers, so they are less conspicuous to potential adversaries.

The team, led by Dr. Richard Cobb, recently developed a novel control technique called Bi-harmonic Amplitude and Bias Modulation (BABM), which can generate forces and moments in five vehicle degrees of freedom with only two actuators. Several MAV prototypes were designed and manufactured with independently controllable wings capable of prescribing arbitrary wing trajectories similar to the biological flyers. Experimental measurements verified that a prototype can generate uncoupled forces and moments for motion in five degrees of freedom when using the BABM control technique, and these forces can be approximated by quasi-steady blade-element formulae. Future testing is planned to demonstrate controlled flight in a series of constrained motion experiments, further demonstrating the feasibility of BABM and enabling FWMAVs for the warfighter.



Contact: Dr. Richard Cobb
937.255.3636 x4559
richard.cobb@afit.edu

Air Force Crash Damage or Disabled Aircraft Recovery Program Resourcing Improvements

Maj Dain O. Kleiv, a June 2011 Department of Operational Sciences graduate, researched the regionalization methodology and cost benefit analysis for the Aircraft Crash Damaged or Disabled Aircraft Recovery (CDDAR) program to provide better management and maximum utilization of scarce resources. This research will provide the Air Force Logistics, Installations and Mission Support (AF/A4) with a methodology to resource the CDDAR program and offer recommendations for improvement in current management processes to enable better utilization of scarce resources.

CDDAR was developed by the Air Force to ensure there are trained technicians and equipment available to recover damaged or disabled aircraft and reopen the airfield for operation as quickly as possible. Maj Kleiv's research focused on equipment utilization and placement of airbags and consoles, which are the most costly of all CDDAR assets in the field. According to the calculations used in his research, the Air Force could save up to $50 million in inventory alone when a regionalization approach to CDDAR program management is implemented.

Maj Kleiv's thesis received the 2011 Jerome G. Peppers, Jr. Outstanding Student Award by the International Society of Logistics, which is given in recognition of academic record and research that contributes significantly to the field of logistics.

Contact: Dr. William Cunningham
937.255.3636 x4283
william.cunningham@afit.edu

Noncombatant Evacuation Operations for USEUCOM

Under the advisement of Dr. J.O. Miller in AFIT's Department of Operational Sciences, Operational Analysis IDE students, Maj Christopher Olsen and Maj Mark Scheer, developed a flexible discrete event simulation model to examine Noncombatant Evacuation Operations (NEO) for the United States European Command (USEUCOM).

NEO is the primary method employed by the Department of State for safely evacuating United States citizens and designated host country nationals from life-threatening situations in foreign countries. The processes that make up an NEO start with the Evacuation Control Center (ECC), where evacuees report for initial identification and screening, then go through an array of transportation factors, where the evacuees are delivered to a temporary safe haven. Planning for these operations is difficult due to the dynamic nature and complex inter-department command and execution structures.

Key strengths, weaknesses, and trade-offs were identified and mitigated by modeling and analyzing the NEO plan, which resulted in a more robust plan and greater chance of operational success. The simulation developed by the AFIT research team can easily be adapted to manage NEO plans across all combatant commands and the Department of State. Details of the ECC and transportation options for country specific operational plans under various assumptions were briefed to Maj Gen Harold W. Moulton II of USEUCOM/J3. Maj Gen Moulton II stated that the model and study completed by AFIT was "hugely beneficial" and provided the "potential to save AMCIT lives in future NEOs."

Contact: Dr. John O. Miller
937.255.3636 x4326
john.miller@afit.edu

Passive Ranging Technique Demonstrated Against a Moving Target

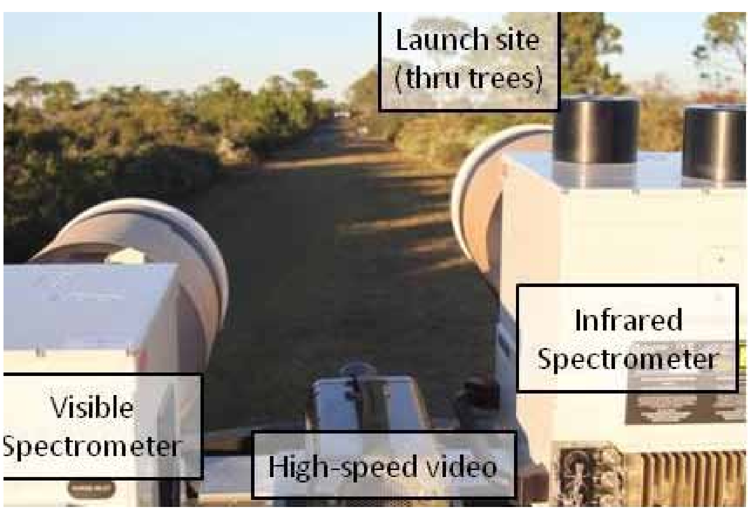
In December 2010, AFIT's remote sensing team deployed to Cape Canaveral, Florida, to test against a moving target for the first time and obtained accurate range estimates during the first 90 seconds after rocket launch, as predicted. AFIT's instruments were mounted on trackers operated by the Innovative Science and Technology Experimentation Facility (ISTEF).

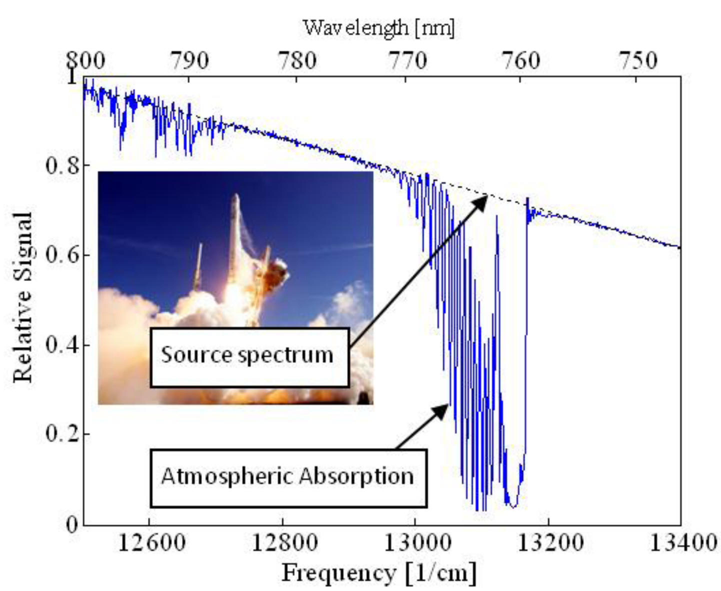
AFIT has demonstrated very accurate range estimation based on atmospheric absorption. Certain frequencies of light are absorbed more strongly than others as the light travels from the rocket plume to our sensor. By carefully comparing these differences, we can measure how much air the light travelled through. When combined with atmospheric models, this can be translated into range. Previous ground demonstrations of this technique were very accurate (range error consistently below 3% in all tests) but limited to static tests due to equipment limitations. This project enabled the first test of AFIT's method against a moving target.

Because this method relies on atmospheric absorption, it cannot function if the missile is in a vacuum. Pre-launch analysis predicted that, 60 seconds after launch, the rocket would be at altitudes where accuracy would degrade; approximately 90 seconds after launch, range estimation would become impossible. AFIT's sensors provided accurate range estimates up to the expected 60-second mark (range error < 8%). Range estimation was still possible (although with increased noise) until track was lost 100 seconds after ignition. While range error in this test was higher than in static tests, the sensor performed exactly as expected for the given trajectory. This confirmed our models, which predict a capability to accurately locate missiles launched over 100 km from a high-altitude airborne sensor. Such a capability would be a key enabler for missions, such as boost-phase missile defense. AFIT is preparing for future flight tests, including developing a more robust sensor.

This research was funded by AFIT's Faculty Research Council, and the results prompted the creation of a new AFIT-led project under National Air and Space Intelligence Center (NASIC) sponsorship. The project started in May 2011 with the goal of developing a prototype sensor to enable more testing under more relevant conditions.

Contact: Lt Col Michael Hawks
937.255.3636 x4828
michael.hawks@afit.edu





Above: Testing site. Right: Measured spectrum from the rocket plume, along with the estimated source spectrum inferred from data outside the absorption band. The difference between the source and measured spectra is related to distance.

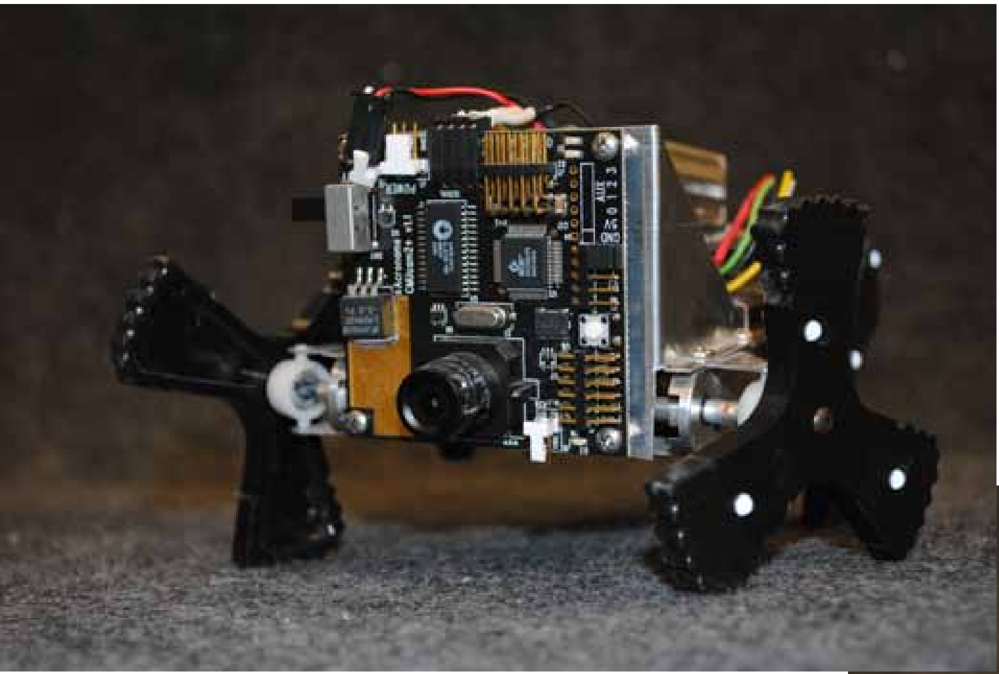
Optical Flow-based Odometry for Underground Tunnel Exploration

Authorities have discovered 75 tunnels along the U.S.-Mexico border in the past four years. Discovering and determining the origin and destination of these tunnels is gaining increasing importance to ensure the safety and security of the U.S. border. In the underground tunnel environment, navigation based on GPS is not possible due to the obstructed view of the sky, so an alternative navigation method with equal precision is required. Researchers in the Advanced Navigation Technology (ANT) Center are exploring the use of cameras mounted on robotic platforms (or vehicles) to investigate and characterize these tunnels.

Small downward-looking cameras attached to a vehicle can be used to track position and heading changes. Images are taken so quickly that the same scene is captured in two consecutive images. By comparing the two images and examining their differences, one is able to determine the distance traveled, as well as information about the vehicle's movement. There are similar vision-aiding techniques already being used at AFIT to track features within consecutive images; however, these methods require distinguishable objects in the environment to work well. Since tunnels and similar environments lack specific features, comparisons are being done pixel by pixel to determine where the image overlap occurs. Frequency domain calculations decrease the computational time during image comparison, which allows the system to handle large amounts of camera data. Also, using two cameras (as opposed to one) prevents ambiguity and produces a position and heading solution, since issues arise when the vehicle turns a corner.

This research, sponsored by the Airbase Technology Division (AFRL/RQX) at Tyndall AFB, Florida, helps solve the growing need to investigate underground tunnels autonomously (where GPS is not available) with a new image registration technique. These algorithms are currently being considered for implementation into hardware prototypes at the Space and Naval Warfare Systems Command (SPAWAR) in San Diego, California.

Contact: Maj Kenneth Fisher
937.255.3636 x4677
kenneth.fisher@afit.edu



Above and right: Examples of robotic platforms to be used in future underground exploration.

Uranium Applications Go Far Beyond Nuclear Fuel

When most people think about uranium, they are focused on its use in nuclear fission. Although its nuclear and radioactive properties are important, uranium has many applications outside of nuclear fuels. Dr. James Petrosky, Associate Professor in the Department of Engineering Physics, is exploring the structure of uranium for other purposes.

Knowledge gained in this research has implications for typical fuel research, such as in the aging of reactor fuel and studies of proliferation-resistant nuclear fuel. Dr. Petrosky contends that uranium metal and various uranium compounds can be used for a new genre of applications that may take advantage of unique physical, electrical, and radioactive properties, such as in radiation-hardened electronics for deep space applications or in special neutron detectors with very high sensitivity to single neutron interactions.

Above: An AFIT student works with an electron paramagnetic resonance spectrometer.

The development of these new applications requires a full understanding of the electronic structure of uranium in order to devise a method for creating stable solid-state electronic structures. AFIT students and faculty members have developed a high level of expertise in recent years in determining the electronic structure of rare-earth-based compounds that are physically similar to uranium compounds. This research was built around AFIT's collaboration with Dr. Peter Dowben's research group at the University of Nebraska-Lincoln's Center for Materials and Nanoscience and the Center for Advanced Microstructures and Devices at Louisiana State University. AFIT will apply the capabilities developed in this collaboration to research uranium's electronic structure and properties. This, along with other spectroscopic techniques, will help determine the best approach to better understanding uranium structure.

An experimental photoemission system is currently being assembled by Dr. Robert Hengehold in AFIT's Department of Engineering Physics laboratory. This system will use photoemission spectroscopy to provide information about the electronic structure and properties of uranium. It will enable preliminary studies of uranium thin films and provide the basis for the exploration of more complex uranium-based structures.

The ultimate goal of this research effort is an understanding of uranium's fundamental physical and material properties that will guide the design of novel uranium-based devices and uranium's response to aging and varying environmental conditions.

Contact: Dr. James Petrosky
937.255.3636 x4562
james.petrosky@afit.edu

Bachelor's to PhD Program Offers Another Option to Fill Critical Air Force Nuclear Positions

To relieve the Air Force's shortage of mid-career-level officers with a nuclear engineering or related technical PhD, AFIT now offers a bachelor's to PhD program. The new program provides students with the opportunity to complete a PhD in four years, which is six months less than the traditional 18-month nuclear master's program that is then followed by three additional years for the PhD.

This program selects from highly qualified applicants with a strong academic record and interest in technical nuclear-related research and advances them through a master's degree with an early start on research and an accelerated course load. It is expected that the master's research will seamlessly become part of the PhD research to allow for a reduced time in residence at AFIT to meet degree requirements.

AFIT Advances Deterrence through Development of a New Graduate Certificate Program

AFIT's Department of Engineering Physics nuclear engineering program has developed a Nuclear Weapons Effects, Policy, and Proliferation (NWEPP) graduate certificate program. The program is designed to provide graduate-level education in nuclear weapons, deterrence, and policy for those without a technical nuclear master's degree who are entering into a nuclear field or may be considering it. The three 4-credit graduate courses in NWEPP are offered via distance learning technology, using relevant videos, readings and interactive sessions designed by experienced AFIT faculty members to provide a high quality learning experience. The first offering of the certificate program began in fall 2011 with 20 students, primarily from the USAF Global Strike Command.

Contact: LTC John McClory
937.255.3636 x7308
john.mcclory@afit.edu

Dr. Marlin U. Thomas presents a photo of the old reactor facility to Gen Edward A. Rice, Commander of the Air Education and Training Command, while standing in Area B, Building 470, during his visit to AFIT on June 7, 2011.

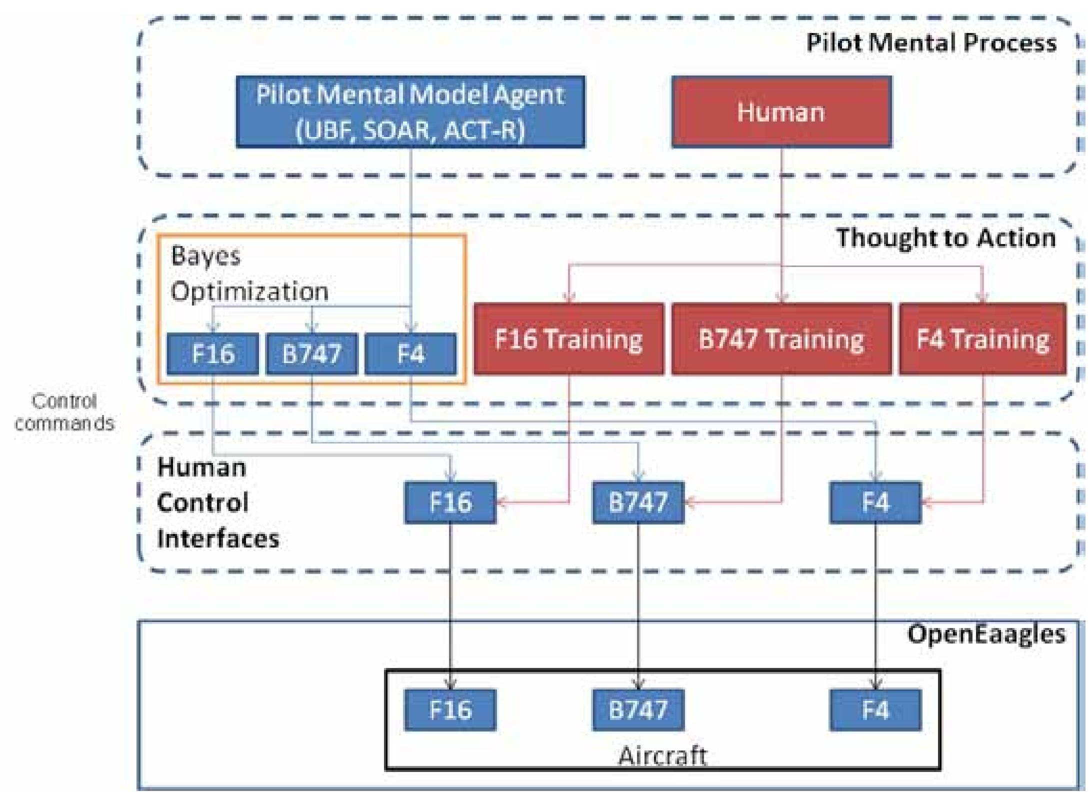
Building 470 is the Air Force Nuclear Engineering Test Facility (NETF). The NETF was initially built to develop a nuclear powered aircraft. The reactor was decommissioned in 1971, but the buildings now support research and education in AFIT's nuclear engineering program and houses the AFIT Model Fabrication Shop which supports AFIT student research and development projects in experimental laboratories and classrooms.

Improved Pilot Models For Simulation

The UBR-Brawler project is a collaborative technical transition between the Advanced Navigation Technology (ANT) Center and Simulation and Analysis Facility (SIMAF) to add unmanned agents to the OpenEaagles simulation framework. The resultant system will reduce the number of human pilots required to support training exercises, distributed tests, and analytical studies. The unmanned agents being developed will replicate the mental processes that pilots use during execution of a mission.

Because the simulation is designed for human pilots and contains highly accurate aircraft models, a significant challenge is providing a method to abstract the interface of the aircraft, so the same pilot process models can be used for many different aircraft. We are using Bayesian Optimization, which is a combination of reinforcement learning and optimal action selection, to learn (for each aircraft) the same pilot thought to action that human pilots receive when training on a single aircraft. The thought to action middleware provides a consistent interface to the pilot process model and sends the correct signals to the aircraft interface.

Future research will concentrate on developing pilot behavior and mental models based on recent advances in psychological and sociological theories on pilot behavior. The instantiation of these pilot mental models will use the ANT Center's Unified Behavior Framework (UBF), which provides a means to generate multiple reactive agents quickly and easily. The UBF assembles several low-level reactive behaviors that are small enough that writing them is simple; for example, executing a roll to avoid a missile. Through the combination of many of these reactive behaviors, the resulting agent can complete complex tasks that match the pilot's mental processes. Because the UBF provides a means to quickly exchange and manipulate behavior components, a range of pilots, from unskilled to skilled and with a wide variety of missions, can be generated and experimented with quickly. This will provide a unique capability to add unmanned agents to simulations and reduce the number of individuals that must support a training exercise, distributed test, or analytic study.



Contact: Dr. Gilbert Peterson
937.255.3636 x4281
gilbert.peterson@afit.edu

Expanding Satellite Operations

AFIT is developing an enhanced ground station command and control systems architecture to allow the operation of multiple satellites. This is a significant expansion from current ground station operations used solely with FalconSAT-3 (FS-3). The new systems architecture will allow expanded operations with FS-3 and future satellites, beginning with an AFIT-developed CubeSat scheduled for launch in 2012.

AFIT uses FS-3 as a classroom tool to allow hands-on teaching of satellite operations. There are 35 AFIT students annually that download telemetry data, operate science payloads, and diagnose simulated problems "on the fly" while cadets at the United States Air Force Academy (USAFA) command FS-3 into various different modes independently from operators at AFIT. In addition to the FS-3 ground stations in operation at USAFA and AFIT, new FS-3 ground stations are being built at the United States Military Academy and Vandenberg AFB, California. This extension will expand the technical curriculum in Space 100, allowing all new officers and enlisted engineers and operators to fly and analyze the data of real satellites. The new network will improve each organization's leveraging of FS-3 by allowing more data collection and operations. AFIT will optimize use of FS-3 across all sites via Discrete Event Simulation of the network based upon geography, crew availability, and operational scheduling.

AFIT's experience with FS-3 is being used as a pathfinder for the ground station development for future AFIT satellites. Scheduled for launch into Low Earth Orbit (LEO) in 2012, AFIT's next satellite will study the degradation of the electric field around Carbon Nanotubes (CNTs) in space by using an Integrated Miniaturized Electrostatic Analyzer (iMESA). ALICE, the AFIT LEO iMESA CNT Experiment, is a CubeSat, a small 30 cm x 10 cm x 10 cm nano-satellite with standardized interfaces that can manifest as a secondary payload on a variety of launch vehicles. AFIT's ground station expansion from FS-3 to ALICE also includes incorporating capabilities for the next generation of CubeSats. Balancing the different satellite ground station requirements and interfaces is best used through a systems architecture. The systems architecture will ensure that all requirements of the FS-3 network and ALICE are met, while also allowing AFIT to expand ground station operations to accommodate future satellites.

Contact: Col Timothy Lawrence
937.255.3636 x4410
timothy.lawrence@afit.edu

Left: Screenshot of FalconSAT-3 orbit.
Below: AFIT students operating ground station computer.

Responsive Spacecraft Maneuvering

New satellite maneuvering techniques developed at AFIT suggest that LEO maneuvers are feasible, contrary to common preconceptions. AFIT's results contribute to solving the "responsive space" problem, an area growing in prominence within the DOD.

The term "responsive space" represents a shift from a solution-oriented to a capabilities-oriented approach to space acquisition and space system design. Responsive space has been dominated by the development of spacecraft and launch vehicles, but one key aspect of the initiative that has garnered increased attention within the defense space community is the exploration of new and novel orbits and maneuvers designed to enhance the operational responsiveness of a given space system in short-duration missions.

Dr. Jonathan Black, Assistant Professor in the Department of Aeronautics and Astronautics, and his students have researched a new technique from the ground track point-of-view to alter the over-flight path of a satellite with existing technology. Using terrestrial distance as a metric between a reference orbit and desired orbit (one that over-flies a given ground target), studies confirmed that a change spanning the globe is possible using existing technology and a change in velocity of 50 miles per second within a period of 24 hours. This finding counters the preconception that LEO maneuvers are too cost-prohibitive to be feasible. When the ground-track modification scheme was combined with highly efficient electric propulsion, the findings were even more promising, allowing existing spacecraft to maneuver 15 times or more to overfly multiple geographical targets.

Through parametric study and trajectory simulation, it has also been demonstrated that skip entry maneuvers have the potential to achieve large changes in orbit inclination with less fuel by using the environment of the earth's upper atmosphere to modify the orbit. Compared with the simple plane change maneuver, a notional satellite design employing skip re-entry requires less change in velocity (savings of 14%) than the vacuum-only alternative for shallow flight-path angles (less than 10°) and large changes in inclination (greater than 30°). Dr. Black and his students will continue this research to vary thrust direction and intensity and optimize the maneuvers using minimal fuel.

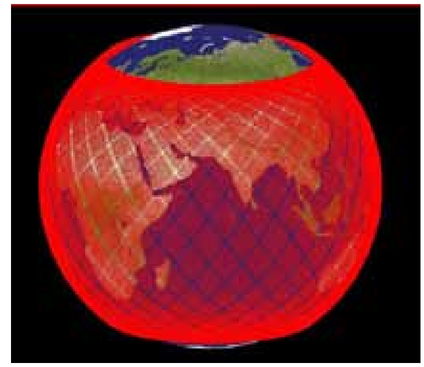
Contact: Dr. Jonathan Black
937.255.3636 x4578
jonathan.black@afit.edu

Patents Issued to AFIT Faculty

Being awarded an issued patent is no small victory. In FY11, AFIT was awarded a record six patents for generated inventions by faculty members.

- "Relocatable Field Programmable Gate Array Bitstreams For Fault Tolerance," Patent No. 7,906,984 – Dr. Rusty Baldwin
- "Shaped MEMS Contact (Geometry)," Patent No. 7,906,738 – Dr. Ronald Coutu and Dr. Paul Kladitis
- "Detecting Software Attacks by Monitoring Electric Power Consumption Patterns," Patent No. 7,877,621 – Dr. Nathaniel Davis
- "LED Device Having Improved Light Output," Patent No. 7,948,172 – Dr. Michael Miller
- "Passive Matrix Electro-Luminescent Display System," Patent No. 7,940,236 – Dr. Michael Miller
- "Electro-Luminescent Display With Power Line Voltage Compensation," Patent No. 7,872,619 – Dr. Michael Miller

Improved Satellite Orbit Predition for Collision Avoidance



Above: The International Space Station seems to envelope the Earth over 30 days. AFIT research has shown that this orbit lies on a KAM torus.

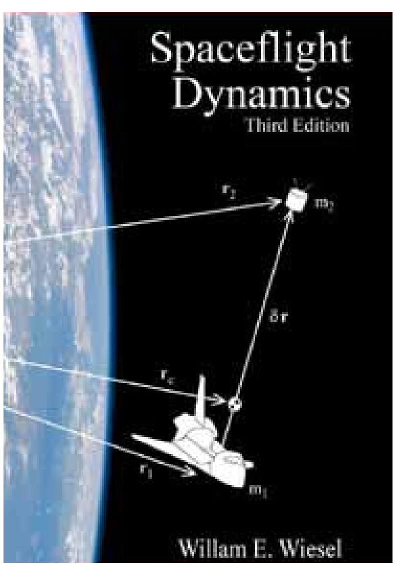
Avoidance of satellite-to-satellite collisions requires a solid understanding of orbit structures and the ability to build models that accurately predict satellite positions over large numbers of orbit cycles. In simple models, a satellite orbit is envisioned as similar to a string being wound around a rotating earth. The string builds up relatively uniformly without expectations of any complex structure. At the level of Sir Isaac Newton's dynamics, a satellite responds from moment to moment to the forces placed on it. These forces include the bumpiness of the Earth's gravitational field, air drag, and the attraction of the moon and sun. Current satellite models are built according to this view but do not provide sufficient accuracy over time to meet future satellite tracking challenges.

A remarkable prediction from the 1950s suggested that there is much more structure to an orbit than was previously thought. Renowned mathematicians, Andrey Kolmogorov, Vladimir Arnold, and Jurgen Moser, credited with the KAM theorem, predicted that most earth orbits should lie on donut-shaped surfaces referred to as KAM tori. In the last few years, AFIT research has shown that most earth orbits do lie on tori; however, they are not simple donuts. Rather, the predicted torus is a three-dimensional structure that lies embedded in a mathematical six-dimensional space of position and velocity components.

AFIT researchers have developed many new techniques to verify and probe this torus structure. The first breakthrough was the realization that earth satellites had the expected frequency structure of a KAM torus. In 2009, this culminated in the agreement between the theoretical torus and a standard numerical construction to within one meter error over 10 years, an unprecedented level of agreement. While this accuracy may never be achieved in the real world, it is critical that we improve our satellite modeling methods to predict, and hopefully avoid, satellite-to-satellite collisions.

Research is currently underway at AFIT to construct practical satellite tracking methods based on KAM torus methods. This effort promises to combine sophisticated KAM algorithms with a simple application and data package that will allow a satellite's orbit to be tracked and predicted to an accuracy of a few meters, sufficient to confirm or deny a suspected possible collision.

Contact: Dr. William Wiesel
937.255.3636 x4312
william.wiesel@afit.edu



Dr. William E. Wiesel is the author of *Spaceflight Dynamics*, the leading text in astronautical engineering with the third edition released last year. This text is an introduction into the dynamics of spaceflight: orbits, maneuvers, satellite stability and control, rocket performance, and reentry.

The Impact of Individual Deployments

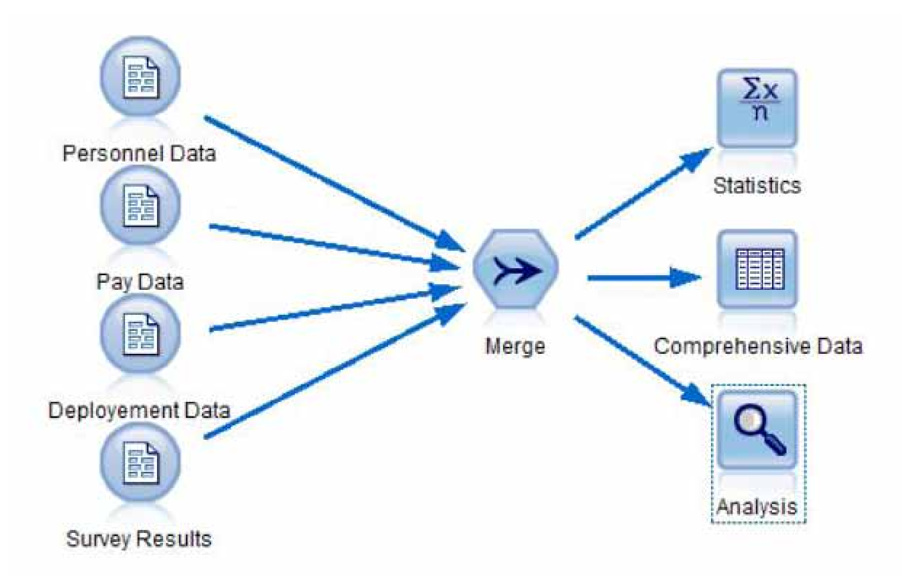
In support of the Office of the Undersecretary of Defense for Personnel and Readiness (OSD P&R), Center of Operational Analysis (COA) researchers in the Department of Operational Sciences mined over 200 million personnel records from the past 10 years, including pay, contingency deployment, and survey results, to investigate the impact on military personnel who deploy individually, as opposed to with a traditional unit.

The OSD P&R is the senior policy advisor on recruitment, career development, pay, and benefits for nearly 3.4 million active duty military, Guard and Reserve, and DOD civilians. They are also responsible for overseeing the state of military readiness. With the assistance of the Defense Manpower Data Center (DMDC), COA researchers, led by LTC Darryl Ahner and Lt Col Sharon Heilmann, linked personnel databases using IBM SPSS Modeler software and identified metrics that would impact the mission of OSD P&R. Several primary metrics were investigated, including operational tempo (OPTEMPO), attitudes and expectations, career progression, and readiness of personnel and units across the DOD.

Individual deployments differ from unit deployments in many respects. They are generally less predictable, and many are filled on short notice, giving service members and their families less time to prepare. While this may seem taxing on the individual, the outcome of this research revealed quite the opposite. Service members are happier overall and have higher job satisfaction and retention rates. Another important aspect of this research exposed the shortfalls that exist within the current personnel data system. Analysis of particular skilled groups that may have an extremely high OPTEMPO has been identified for further investigation.

Quarterly in-progress reviews with OSD P&R assisted researchers to zero in on critical questions by senior-level DOD decision makers. This comprehensive, ongoing study has the potential to impact a wide range of personnel, training, readiness, and deployment policies within the DOD.

Contact: LTC Darryl Ahner
937.255.3636 x4708
darryl.ahner@afit.edu



Reballasting the KC-135 Fleet for Fuel Efficiency

The KC-135 aircraft is the United States Air Force's first jet-powered refueling tanker. It was subject to numerous upgrades over the first 50 years of service to adapt to new and expanded mission requirements. These changes have added a large amount of weight to the aircraft, with much of it focused in the rear of the airframe, which created an aft center of gravity (CG). Boeing accounts for this aft CG by requiring that ballast (counter balance) fuel be carried in the forward body tank to maintain a CG forward of the aft limit.

Maj Phil Morrison, a graduate student in the Advanced Study in Air Mobility (ASAM) program, and his AFIT advisers, Lt Col Christopher M. Shearer and Maj Dan Mattioda, developed a linear programming model that calculates the exact weight and location for ballast for each KC-135R aircraft in the Air Force inventory, while keeping it within the flight envelope.

Boeing Engineering Analysis acknowledged that 3,500 lbs of fuel is required in the forward body tank, which is strictly for ballast. Using fuel in the forward body tank for ballast has two significant drawbacks: (1) the forward body tank has a very short moment-arm, necessitating more weight than that of ballast on a longer moment-arm, and (2) ballast fuel displaces fuel that could be used for mission purposes by using the tank to hold ballast weight. Reducing aircraft gross weight is a cost issue, because excess weight incurs a "carriage cost." The "carriage cost" for weight on the KC-135 is 4.97% of the weight in pounds of fuel burned per hour.

The significance of the weight reduction garnered by the research amounts to approximately $400 million in reduced fuel expenditures over the projected life of the fleet and significant mission capability improvements, including a design ballast addition funded by Boeing for $650,000.

Contact: Maj Daniel Mattioda
937.255.3636 x4510
daniel.mattioda@afit.edu

This research was awarded the AFIT Military Operations Research Society Award and the Air Force Historical Society's Bryce Poe Award and was recognized by AMC's Energy Incentive Award program in 2010.

The Impact of Snow Removal on Pavement Markings

Snow removal methods, such as plowing or applying salt, and other ice-melting chemicals can make travel on the roads easier and safe, but it can also negatively affect pavement markings. Lt Col William Sitzabee and students from the Department of Systems and Engineering Management researched the impact of snow removal and deicing operations on pavement marking retroreflectivity degradation in collaboration with the North Carolina Department of Transportation (NCDOT).

An initial analysis completed by NCDOT revealed significant results and quantified the impact of snow removal on pavement markings for both thermoplastic and paint pavement marking. The degradation models determined that several factors impact pavement marking degradation, including lateral location, initial retroreflectivity, traffic volume, and directionality. This prompted AFIT to perform further research to explore the impact of snow removal on pavement marking degradation.

AFIT's first model, based on data from NCDOT, was applied on a stretch of road in Ohio to explore the utility of the model in other states. Recently proposed Manual of Uniform Traffic Control Devices minimum standards for pavement marking retroreflectivity were combined with the newly developed degradation model to determine the remaining service life of four road segments due for replacement according to standard operating procedure. The model indicated three years of service life remaining for two of the road segments, indicating that replacement is unnecessary. By using this model, the remaining service life of a paint pavement marking can be estimated, and asset managers can avoid premature replacement of pavement markings. A key finding of this research is that each snow removal event subtracts more than one month of service life from paint pavement markings.

Above: Retroreflectometer on test locations.

AFIT students completed further research, which included two studies on the longevity of pavement markings; specifically, polyurea and thermoplastic pavement markings. The study on polyurea markings found that retroreflectivity and longevity of pavement markings is significantly impacted by the size of glass bead implanted into the paint.

Researchers hope to apply the same model for Air Force Civil Engineering Support Agency (AFCESA) and AFRL to extend pavement marking research to airfield runways, determining the longevity of runway pavement based on a variety of variables. The research will identify plausible materials to be used on airfields and asset management principles to decrease the amount of time runways are shut down for rubber removal and restriping operations.

Contact: Lt Col William Sitzabee
937.255.3636 x7395
william.sitzabee@afit.edu

Improved Modeling of IEDs

AFIT researchers have developed improved methods to determine the radar cross-section (RCS) of improvised explosive devices (IEDs), which are the number one threat on today's battlefield in Iraq and Afghanistan. An IED typically resembles a cavity with protrusions above the surface from a radar scattering viewpoint, although IEDs are designed in many various forms. This puts a significant component of the IED radar detection problem into a class of electromagnetic cavity scattering problems that have interested researchers in mathematics and engineering for decades.

From a mathematical perspective, previous research generally simplified cavity scattering problems in three main areas: boundary conditions, problem geometry, and domain of study. In seeking a more broadly applicable model relevant to IED detection, we enforced impedance boundary conditions, or boundary conditions of the third kind, which represent the earth's surface more accurately. We also assumed an overfilled cavity to model an IED more accurately with protrusions or disturbances above the ground. In addition, we modeled the problem in the time domain due to a growing demand in the military for wideband modeling and more accurate modeling of transient phenomena.

After establishing the soundness of this improved mathematical model of the physical system, we implemented the theory numerically by providing RCS measurements and visual depictions of the scattered waves. AFIT's research results are a significant advancement from previous work where more simplified conditions were used, which can limit the number of applications. The new approach also aids in the study of cavity like structures on aircraft and vehicles, as well as in the detection of IEDs.

Contact: Dr. Aihua Wood
937.255.3636 x4272
aihua.wood@afit.edu

Strategic-Level Asset Management for the Civil Engineer Community

Lt Col William Sitzabee and student, 1Lt Marie Harnly, are leading a collaborative, 18-month study on strategic asset management modeling for the Civil Engineer community. Endorsed by HQ Air Force, AETC, AFMC, and Civil Engineer School, this research develops a strategic-level asset management model that provides guidance and establishes a framework for effective asset management. The strategic model also incorporates Next Generation Information Technology initiatives, such as elimination of redundant data collection, into a single coherent system in order to streamline the top down, bottom up flow of information.

The strategic-level asset management model is applicable to agencies with a large infrastructure inventory and limited resources. This research develops the performance modeling tool, a critical component of the strategic model. The performance modeling tool objectively prioritizes maintenance and repair projects according to measurable metrics and established goals and policies. The strategic-level model and performance modeling tool enable policy-makers to make decisions that tie goals, infrastructure inventory, condition state, and budget constraints to system performance.

The results of this research study include a new funding priority equation that enables Civil Engineer leadership and asset managers to effectively manage over $2.5 billion of the annual operations and maintenance budget. The equation provides a prioritization that meets stated goals for energy and water reduction and improved space utilization.

See Page 26 for contact

Assessing the Nuclear Devastation in Japan

In the aftermath of the March 11, 2011, earthquake off the northeast coast of Japan, LTC Eugene Sheely, Assistant Professor of Chemical Physics, deployed to Honshu, Japan, where he served as the team leader of the Defense Threat Reduction Agency Consequence Management Advisory Team. LTC Sheely assisted with determining both the short- and long-term effects of the Fukushima Daiichi Nuclear Power Plant disaster on the Japanese people, as well as United States DOD personnel and their families currently stationed there.

LTC Sheely and his team assessed several factors and advised on the effects of radiation on the quality of life in the surrounding areas post-meltdown, which included living conditions, food, natural environment, and the evacuation zone. Radiation levels were tested using measuring devices placed on a bullet train that runs from Tokyo to Sendai, approximately 50 km from the reactors. The max radiation level found was 52 micro-radians per hour. The Nuclear Regulatory Commission allows non-radiation workers to be exposed to up to 2000 micro-radians per hour, and radiation workers can be exposed to much more. No negative health effects have been demonstrated for doses this low.

LTC Sheely and his team provided three main recommendations for the DOD: 1) DOD radiation workers performing legitimate approved missions should be allowed within the evacuation zone, 2) United States DOD restrictions on travel outside the Japanese evacuation zone should be lifted and replaced with an advisory equal to the state department advisory, and 3) Restrictions for those living within 80 km of the Fukushima Daiichi reactors should be maintained in order to see how conditions at the plant stabilize as more data become available.

Contact: LTC Eugene Sheely
937.255.3636 x4569
eugene.sheely@afit.edu

Left: Satellite image of the four damaged reactor buildings at the Fukushima Daiichi Nuclear Power Plant. (Photo made available by DigitalGlobe)

AFIT hosts AFOSR Seminar Series Speaker, Sir John Pendry

Air Force Office of Scientific Research (AFOSR)-funded researcher, Sir John Pendry, spoke to a crowd of over 200 on November 14, 2011, at AFIT as part of the AFOSR Seminar Series and in celebration of AFOSR's 60th anniversary.

From left to right: Sir John Pendry, Dr. Thomas Hussey (AFOSR Chief Scientist), and Dr. Michael Marciniak (AFIT Associate Professor).

Sir Pendry is a condensed matter theorist and Chair in Theoretical Solid State Physics at the Imperial College in London. He is renowned for his research into refractive indexes and the creation of the first practical "Invisibility Cloak." His seminar, Inside the Wavelength–Seeing Really Small Objects With Light, addressed one of his most notable achievements: the theory for the perfect lens that has no limits to resolution, which could yield a microscope that can resolve objects smaller than the wavelength of light.

Dr. Thomas Hussey, AFOSR Chief Scientist, presented Sir Pendry with an official AFOSR 60th Anniversary coin, recognizing him for his outstanding contribution to AFOSR's 60-year history of funding the best and brightest researchers on the forefront of scientific discovery.

For more information about the AFOSR Seminar Series, visit http://www.afit.edu/en/ENR/AFOSR_Seminar_series.cfm

Preparing STEM Students for the Future

Students from the Dayton Regional Science, Technology, Engineering, and Mathematics (STEM) School visited AFIT as part of their "Power Lunch" series, which is based on "show and tell" presentations by participating STEM partners in the Dayton area. The students met with CCR research engineers to learn about current research, ongoing cyber threats, and careers in cyber security.

The ANT Center also hosted middle school students participating in Air Camp, a program designed to inspire students discover how science, technology, engineering and math relate to the real world of aviation. The students were given a tour and overview of the Center and learned about different types of navigation. They also participated in a geocaching exercise, a real-world outdoor treasure hunting game in which players try to locate hidden containers, called geocaches, using GPS-enabled devices.

Left: Air Camp students get ready to participate in a geocaching exercise.

Maj Matthew Robbins, PhD

In 2011, Maj Matthew Robbins, Assistant Professor in the Department of Operational Sciences, was honored by the NSA as a Distinguished Visiting Professor for its Summer Program for Operations Research Technology (SPORT) at Fort Meade, Maryland.

Leveraging his highly specialized talents, Maj Robbins advised and mentored the SPORT graduate students in the identification and translation of NSA problems into an appropriate operations research study effort. Maj Robbins guided investigation into the modernization of NSA's query compliance framework, which is designed to provide reasonable assurance that queries adhere to the legal authorities and restrictions governing NSA's SIGINT mission. Additionally, Maj Robbins shared high-level operations research techniques with the students to identify improvements and semi-automation of auditing practices that may increase efficiency by up to 100%, enabling reallocation of resources from compliance to mission requirements.

> At AFIT, our highly motivated faculty and graduate students have the opportunity to apply operations research techniques to some of the most important defense-related research issues of the day and provide meaningful analyses to interested partners across the DOD.

Maj Robbins joined the AFIT faculty in 2010. He has been recognized with a number of awards, most notably winning the 2011 Pritsker Doctoral Dissertation Award (First Place) from the Institute of Industrial Engineers (IIE). The annual IIE Pritsker Doctoral Dissertation Award recognizes outstanding graduate research in the field of industrial engineering.

Christine Schubert Kabban, PhD

Dr. Christine Schubert Kabban joined the Department of Mathematics and Statistics at AFIT in July 2010. She is actively involved in numerous Air Force research projects, using a wide variety of statistical techniques, including designing clinical trials, advanced and structural equation modeling, categorical and classification techniques, and even simple t-tests.

Dr. Schubert Kabban received her PhD in Applied Mathematics at AFIT in 2005. While a student at AFIT, she was a recipient of a Dayton Area Graduate Studies Institute (DAGSI) scholarship, which allowed her to work in the area of information fusion. She has authored/co-authored over 40 journal articles; presented and been an invited speaker in over 13 conferences, and served as a member of an NIH working group; as well as an advisor or committee member for over 15 graduate PhD and master's students.

> The dedication and knowledge of AFIT faculty, students, and staff create an exceptional environment not only to achieve teaching and research success, but to create solutions for concomitant Air Force labs and programs that help shape the Air Force of tomorrow.

Eileen Bjorkman, Col, USAF (Ret.)

Ms. Eileen Bjorkman, currently a senior-level executive serving as Technical Advisor at the Air Force Flight Test Center at Edwards AFB, California, has had an exciting career since earning distinguished graduate honors at AFIT. Prior to her retirement at the rank of Colonel, she flew more than 700 hours as a flight test engineer in over 25 different aircraft, primarily the F-4, F-16, C-130, and C-141. She also served as an instructor and test squadron commander.

Ms. Bjorkman was named the Military Analyst of the Year in 1995 and Military Tester of the Year in 2008. She has been published several times in the International Test and Evaluation Association Journal and is currently working on a PhD in Systems Engineering. Ms. Bjorkman advises students to "never stop learning even after graduating from AFIT." She credits her interest in chaos theory 20 years ago for her ability to understand the complex systems we have in today's Air Force.

Claudia Kropas-Hughes, PhD

A recognized researcher in the nondestructive testing field, Dr. Claudia Kropas-Hughes was awarded the ASTM (American Society for Testing Materials) International Award of Merit for her exemplary technical and administrative leadership and contributions to Committee E07 on Nondestructive Testing. This award is the highest organizational recognition for individual contributions to ASTM standards and activities.

Dr. Kropas-Hughes has more than 25 years of experience, primarily in X-ray-compounded tomography and radiological digital methods. She has worked for the USAF since 1989, holding various positions. She currently provides policies and guidance for technology transition activities with the Air Force Materiel Command.

Dr. Kropas-Hughes received her PhD in Electrical Engineering from AFIT and is a fellow of the American Society of Nondestructive Testing where she currently serves on the Board of Directors.

> My time at AFIT was invaluable to me. I worked with some of the best minds in the country, faculty and students. My career has been shaped by my time there. Air Force issues can be unique and intricate, and solving those problems requires creative and innovative thinking, as well as a dedication to the US Air Force - both of which I learned at AFIT!

Selected Large Awards FY11

TRICARE - $4.1M
"Technical Support, Military Medical System Modeling"
Dr. Rusty Baldwin

National Science Foundation - $799k
"Federal Cyber Service: Scholarship for Service"
Dr. Rusty Baldwin

478th AESG - $706k
"Research, Analysis and Transition to the 478th Aeronautical Systems Group"
Lt Col Timothy Pettit

USTRANSCOM - $450k
"Optimization, Modeling and Logistical Approaches to Improve Deployability and Sustainment of US Armed Forces"
Dr. James Moore

AFRL/RY - $440k
"Side-Channel Analysis Resistant Advanced Encryption Standard FPGA Intellectual Property"
Dr. Rusty Baldwin

AFRL/RD - $411k
"High Power Diode Pumped Alkali Vapor Lasers and Analog Systems"
Dr. Glen Perram

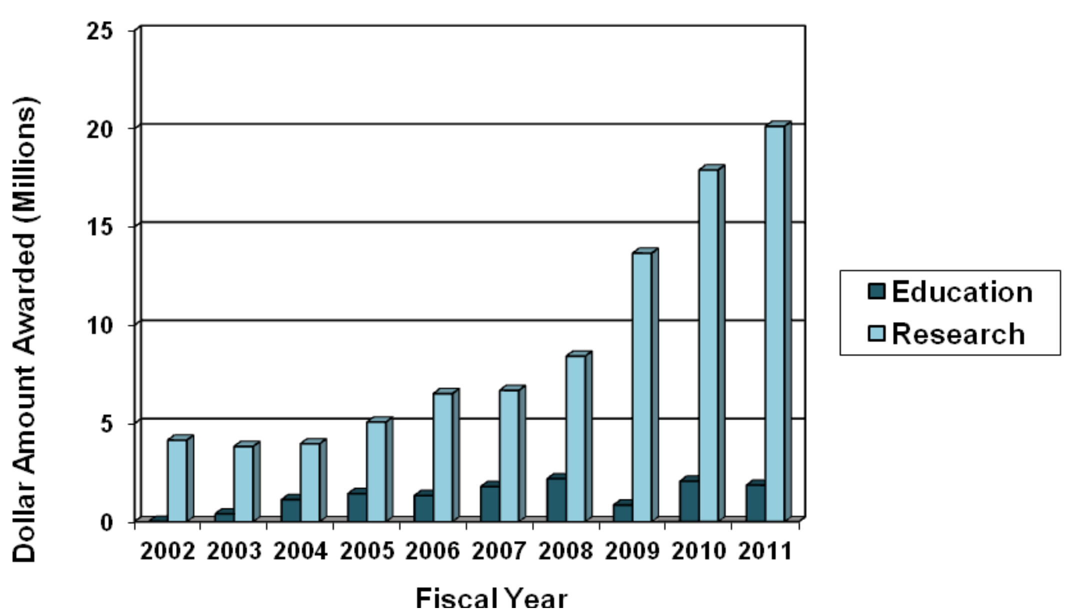
HQ AFMC - $350k
"Research, Analysis and Transition Support to the Director of Logistics and Sustainment AFMC"
Lt Col Sharon Heilmann

AFRL/RY - $347k
"Phase III Support: RF-EW Systems"
Dr. Michael Temple

Office of the Secretary of Defense - $325k
"The Science of Test: Advanced Test and Evaluation in Support of the DOD Test and Evaluation Enterprise"
Dr. Raymond Hill

AFRL/RY - $295k
"Next Generation Radar Range"
Dr. Andrew Terzuoli

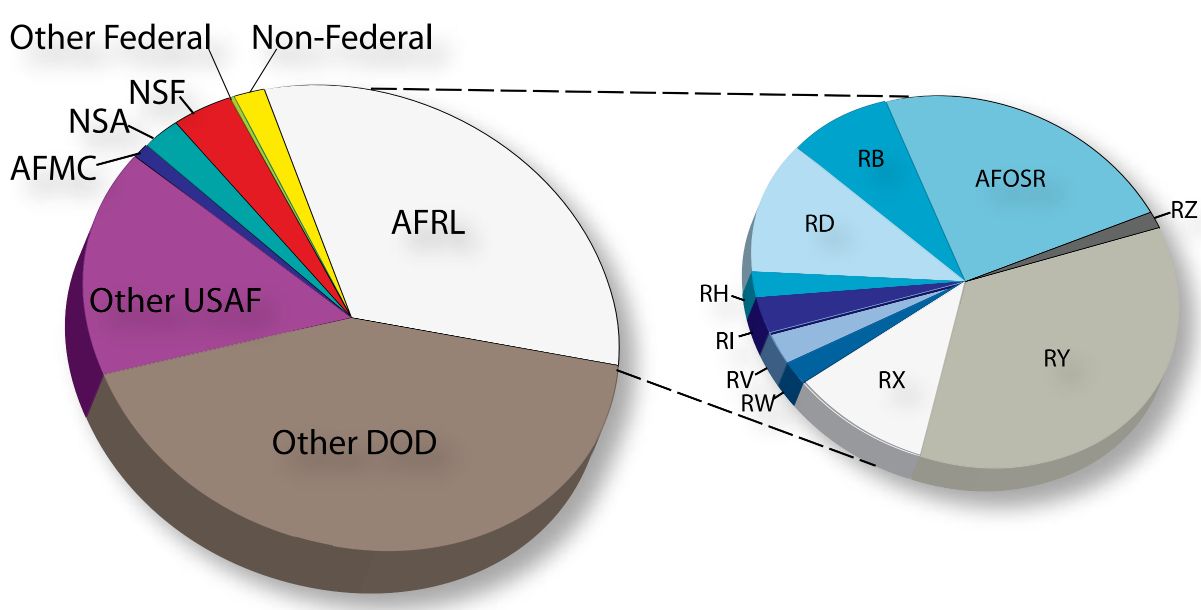
New Award History FY02-FY11



New FY11 Awards to Academic Departments and Research Centers

	Newly Awarded Research Projects		Newly Awarded Education Projects		Total FY11 Newly Awarded Projects		Total FY11 Research Expenditures
	#	$k	#	$k	#	$k	$k
DEPARTMENT							
Mathematics & Statistics (ENC)	11	447	-	-	11	447	603
Electrical & Computer Eng (ENG)	70	9,882	2	1,058	72	10,940	10,893
Engineering Physics (ENP)	35	3,601	4	417	40	4,018	5,987
Research & Sponsored Programs (ENR)	2	39	1	34	3	73	31
Operational Sciences (ENS)	16	3,445	2	23	18	3,468	4,562
Systems and Eng Management (ENV)	14	956	1	267	15	1,223	1,684
Aeronautical & Astronautical Eng (ENY)	45	1,753	2	65	47	1,818	4,346
TOTAL	**193**	**20,123**	**12**	**1,864**	**206**	**21,987**	**28,106**
CENTER							
Advanced Navigation Technology (ANT)	28	2,087	-	-	28	2,087	2,739
Center for Cyberspace Research (CCR)	12	5,935	2	1,058	14	6,993	4,572
Center for Directed Energy (CDE)	17	1,929	1	8	18	1,937	3,202
Center for Technical Intelligence Studies and Research (CTISR)	7	490	2	289	9	779	1,030
Center for Operational Analysis (COA)	17	3,482	2	23	19	3,505	4,645
TOTAL	**81**	**13,923**	**7**	**1,378**	**88**	**15,301**	**16,188**

Sponsors of FY11 Projects



*Pie chart on the right shows breakdown of AFRL Directorates

Enrolling at AFIT for Graduate Studies

The Graduate School of Engineering and Management offers multiple graduate and doctoral degree opportunities that focus on high-quality graduate education and research. We serve the Air Force as its graduate institution of choice for engineering, applied sciences, and selected areas of management. The appeal for our distinct educational opportunities is widespread and attracts high-quality students from other United States armed services, Government agencies both inside and outside the Department of Defense, and international military students. Of particular note, under the National Defense Authorization Act for Fiscal Year 2011, the Graduate School may enroll defense industry employees seeking a defense-related education.

Our automated application system at http://www.afit.edu/en/admissions/index.cfm provides immediate application information to the Office of Admissions; an admission counselor usually contacts the applicant within 24 hours of submitting an application. In addition, there is no application fee. Because of our highly automated admission processes, the Office of Admissions usually renders an admission decision within 15 days.

Prospective students will join a robust and energetic student body focused on learning and research. The Accreditation Board for Engineering and Technology (ABET) accredits most of our engineering programs, not a common factor among graduate schools of engineering. Students usually finish their master's programs within two years and the doctoral programs within three years. Enrollment averages around 750 full- and part-time students with a student to faculty ratio of 6:1. In academic year 2010 – 2011, 371 master's and doctoral degrees were awarded to 290 Air Force officers, 32 sister services, 34 civilians, and 15 international military officers. Our campus consists of8 buildings, 23 class laboratories, 67 research/laboratory areas, and the D'Azzo Research Library.

For more information, visit www.afit.edu/EN/admissions/index.cfm.

AFIT Focused Issue of Air and Space Power Journal

AFIT was recently featured in the Summer 2011 issue of the Air and Space Power Journal (ASPJ). Faculty members solicited papers from a variety of disciplines for publication. The ASPJ is a professional journal of the U.S. Air Force and is designed to serve as an open forum for presentation and stimulation of innovative thinking on military doctrine, strategy, force structure, readiness, and other matters of national defense. To read this issue, go to http://www.airpower.maxwell.af.mil/airchronicles/apj/2011/2011-2/2011_2. pdf.

AFIT Research Centers

Air Force Cyberspace Technical Center of Excellence
Center for Cyberspace Research
http://www.afit.edu/en/ccr/
Dr. Richard Raines

Advanced Navigation Technology Center
http://www.afit.edu/en/ant/
Dr. John Raquet

Center for Directed Energy
http://www.afit.edu/en/de/
Dr. Steven Fiorino

Center for Operational Analysis
http://www.afit.edu/en/coa/
LTC Darryl Ahner, PhD, PE

Center for Technical Intelligence Studies & Research
http://www.afit.edu/en/ctisr/
Dr. Ronald Tuttle

AFIT AT A GLANCE

Scholarly Activity for 2011
- 206 Refereed Journal Articles
- 227 Proposals
- 16 Books and Chapters

Current Enrollment
- 587 Master's
- 131 Doctoral
- 66 Certificate
- 14 Other

Enrollment by Branch of Serivce
- 120 Civilian/Other
- 31 Sister Service
- 26 International
- 12 Enlisted
- 529 Air Force Officers

Land and Buildings
- 533,000 Gross Square Footage
- 35 Acres
- 9 Buildings

18,000+ Alumni

Personnel
- 137 Faculty
- 389 Support Staff