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2007 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

Graduate School of Engineering and Management

ANNUAL REPORT 2007

AIR FORCE INSTITUTE OF TECHNOLOGY

ADVANCED NAVIGATION CENTER
CYBER WARFARE
RESEARCH HIGHLIGHTS
HONORS AND AWARDS
FACULTY FOCUS
SPECIAL TOPICS
RESEARCH DATA

AFIT Overview

What started in 1919 as a school for select officers has grown into a premier educational institution for both military and civilian students, international students, and members of all branches of the armed services. AFIT accomplishes its mission through three resident schools – the Graduate School of Engineering and Management, the School of Systems and Logistics, and the Civil Engineer and Services School – as well as through its office of Civilian Institution Programs.

As the Air Force Institute of Technology continues its ninth decade of operation, faculty and staff members reflect with pride on the contributions the Institute's graduates have made on engineering, science, technology, medicine, logistics, and management. These immeasurable contributions have been vital to national security. The future promises to be even more challenging than the past, and AFIT is prepared to continue providing the environment and the opportunity for our students to develop the professional and technological skills needed to sustain the supremacy of America's air and space forces.

MISSION

Provide responsive, defense-focused graduate and continuing education, research, and consultation to improve Air Force and joint operational capability

www.afit.edu/en

Dr. Thomas, Dean

Message from the Dean

The United States and coalition warfighters must have superior technologies and implementation strategies to defeat the rapidly evolving techniques of our adversaries. The men and women of the Air Force Institute of Technology's Graduate School of Engineering and Management are motivated by this fact to produce the technical achievements summarized in our Annual Report 2007.

AFIT's Graduate School intentionally aligns its education and research programs with critical Air Force, Department of Defense, and national security needs. Last year's report highlighted our cyber warfare activities in direct support of the Air Force's new Cyberspace Command - an area that is still growing rapidly.

The Annual Report 2007 focuses on our Advanced Navigation Technology (ANT) Center's research efforts to support "anywhere, anytime, using anything" navigation and tracking. The ANT Center's research niche directly impacts the precision and robustness of a broad range of military hardware, and leverages the skills of faculty and students from multiple disciplines. Consistent with AFIT's expectations for proactive outreach and technology transfer, the ANT Center has extensive partnerships with the Air Force Research Laboratory, the Defense Advanced Research Projects Agency, other federal agencies, universities, and corporations.

AFIT ranks 8th in the number of master's degrees awarded by U.S. engineering colleges, according to the most recent American Society of Engineering Education survey. While these graduates will provide immediate benefit to the U.S. Air Force and Department of Defense, they will also contribute to the nation's technical workforce and economic strength for decades following their military service. AFIT's research funding from U.S. military and intelligence agencies continues to increase, reflecting the value of our research products to our sponsors.

While proud of our 2007 achievements, the faculty, staff, and I are looking forward with enthusiasm to further innovations and educational improvements in 2008.

Marlin U. Thomas, Ph.D.
Dean, Graduate School of Engineering and Management
Air Force Institute of Technology

The Advanced Navigation Technology Center

Dr John F. Raquet
The Advanced Navigation Technology (ANT) Center, Center Director

AFIT's Advanced Navigation Technology (ANT) Center has been tackling navigation-related technology problems for many years, striving to enhance the capability of precision munitions and the operation of autonomous vehicles. The importance of the ANT Center's research focus was emphasized in September, 2006 when the Joint Requirement Oversight Council (JROC) signed a Joint Capabilities Document (JCD) on Positioning, Navigation, and Timing (PNT).

Dr. John Raquet leads the ANT Center team of over 50 faculty members, students, and staff members who work together to solve a wide variety of navigation-related research challenges. The ANT Center attracts approximately $1M research funding annually from the Air Force Research Laboratory, DARPA, and a variety of other organizations.

Our primary research thrusts are threefold:

- Multiple Vehicle Autonomous Navigation and Control
- Non-GPS Precision Navigation
- Robust GPS Navigation / NAVWAR.

The DoD is increasingly moving toward cooperative (network-centric) warfare, where multiple vehicles interact with each other as they accomplish a mission. When this happens, navigation and timing is almost always fundamental to success. The ANT Center is involved in a variety of projects that develop the autonomous capability of multiple vehicles. Through both theoretical and experimental work, we are attempting to improve the ability to show how results from simpler "toy" problems properly scale to a real system.

UAV-Based Research

Swarm Navigation and Control

Image-Aided Navigation

Precision Formation Flight Control

Multi-Vehicle Remote Sensing

Precise Relative Navigation for Air-to-Air Refueling of UAVs

The Goal:

Current Test System:

Real-time, cm-accuracy relative position and attitude at 20 Hz

The success of GPS for the warfighter (and many commercial applications as well) has shown us the value of navigation. However, GPS does not work in some environments such as under trees, in buildings, under ground, or in the presence of significant GPS jamming. As a result, the ANT Center has been working for the past six years on alternative navigation technologies that will work in situations where GPS does not function. Examples of these technologies include vision-aided navigation, RF-beacon-based navigation, and navigation using signals of opportunity.

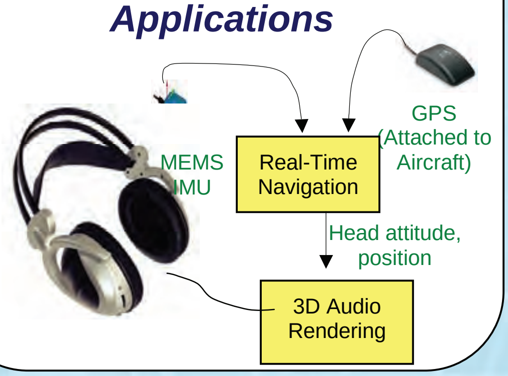
While we are aggressively pursuing many non-GPS navigation approaches, there is still much value in improving our ability to use GPS. We have developed techniques to make GPS systems more resistant to jamming, and have also enhanced the ability to obtain precise (cm-level) positioning accuracy for applications that require it. Additionally, the ANT Center has conducted classified research in the NAVWAR (navigation warfare) arena.

Precision Navigation Anywhere Anytime Using Anything

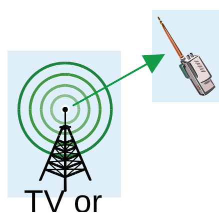
Autonomous Indoor Mapping and Navigation

Multi-robot simultaneous localization and mapping for large domains

INS/GPS Head Tracker For 3D Audio Aviation Applications

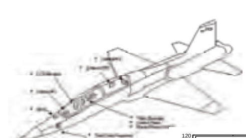


Navigation Using Signals of Opportunity (SoOP)



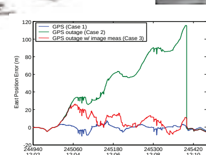
- Built and tested SoOP hardware
- Developed theory of "Navigation Potential"

Optical Aiding of INS



Test Platform

Sample



Results

Image-Based Navigation Meets GPS Performance!

ANT at AFIT

Autonomous Indoor Micro Air Vehicles

We live in exciting times, indeed. The perfect storm of ideas, technology, and motivation that will enable the next-generation of small autonomous vehicles is here. These future vehicles must be able to operate freely and autonomously in all environments, leaving no safe harbor for our enemies.

This fascinating concept is made possible by recent developments in miniaturized inertial, optical, laser, and magnetic sensors. Combining this revolutionary technology with recent innovations in tightly coupling non-traditional sensors with inertial measurements enables precision navigation and targeting in environments that have been traditionally off limits. While this technology is still in its infancy, now is the time to proceed from the laboratory bench to real, interactive systems in real-world environments. This will be the true litmus test for these non-traditional, autonomous systems. Research in this area must be accomplished to truly reveal the most advantageous development path.

Precision navigation is the cornerstone to the modern concepts of precision attack and synergistic combat operations. The Global Positioning System (GPS) was fielded in the 1980s and it is a force enabler which combines the classic tenets of mass and surprise in ways which were previously impossible, leading to the development of the doctrine of precision combat.
The precision combat revolution has led to new tactics and development of a highly focused combat force which exploits a minimum of weapons to produce the maximum effect on the enemy. The Air Force's reliance on precision combat tactics, combined with a lack of alternative precision navigation technologies, has led to a dependence on GPS. Unfortunately, GPS requires a direct line of sight to the satellite constellation and is vulnerable to attack or disruption. Thus, precision combat is currently impossible in areas not serviced by GPS.

The motivation of current work being done at AFIT is to address the limitations of the current precision navigation methods by fusing non-GPS sensors. This concept is inspired by observing the precision navigation capabilities of animals. Research has indicated that animals utilize visual, inertial, proprioceptic, and magnetic field observations to navigate with precision in the air, land, and sea. This powerful natural demonstration of navigation principles guides this effort, which builds on previous research to make precision navigation using visual and inertial measurements possible for military applications. Not only does the fusion of multiple non-GPS sensors with autonomous flight control strategies reduce or eliminate the reliance on GPS, it introduces the overwhelming advantages of precision combat into mission areas which were previously impossible such as urban, indoor, or underground combat.

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Wireless Sensor Network: Energy Use Localization Accuracy

Many applications that use sensor data from a wireless sensor network (WSN) require corresponding node position information as well. Therefore, it is not surprising that a common figure of merit for localization algorithms is the accuracy of the position estimate produced. Similarly, the amount of communication required by a localization algorithm is often of paramount interest as well since it is common knowledge that communication expends the most energy in a WSN. However, localization algorithms seldom characterize their communication cost. Furthermore, when they do it is often merely qualitative and is typically described as "expensive". For two types of range-aware, anchor-free localization algorithms we found the opposite to be true. Rather than being expensive, the communication costs were quite modest. So much so that we maintain range-aware, anchor-free localization algorithms should be chosen on the basis of the accuracy required by the intended application independent of the communication cost.

We examine the effect of node degree, node distribution, range error and network size on distance error and communication cost for both incremental and concurrent versions of range-aware, anchor-free algorithms. The concurrent algorithm is twice as accurate as the incremental, but less efficient. Furthermore, node degree influences the energy cost of the algorithms the most, but neither algorithm used more than surprisingly small 0.8% of a 560 mA h battery. This result indicates less energy efficient localization algorithms can be tolerated, especially if they provide better accuracy. Furthermore, if energy does need to be conserved, there is not much savings available within the localization algorithm and savings must be found in other areas such as the MAC protocol or routing algorithm.

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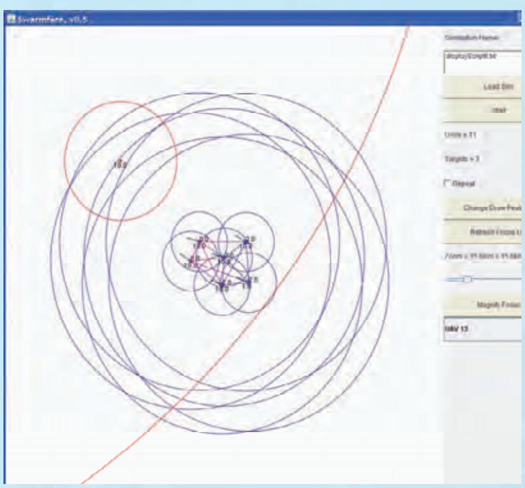
AFIT UAV Swarm Development, Simulation and Analysis Research

3D Vehicle Routing and Visualization of a Swarm of UAVs using Multi-Objective Evolutionary Algorithms

2Lt Adam Pohl's research involves developing multiobjective evolutionary algorithms (MOEAs) solutions for the VRPTW in order to model mission planning for Unmanned Aerial Vehicles (UAV) swarms. Benchmark VRPTW problems, as well as real-world UAV scenarios, are applied to the MOEA algorithm in order to validate construction. Previous work in applying evolutionary search to path planning is also further developed and combined with the new VRPTW routing work. The output of the routing and path planning software is a set of waypoints that can be visualized using the AFIT UAV parallel swarm simulator: documenting, refining the design, implementing the routing algorithm as part of the AFIT UAV Swarm Mission Planning System, and interfacing and modifying the UAV simulation. A desired result of this research is to show that the proposed MOEA solution is effective for developing "optimal" UAV swarms routes, as well as providing 3D swarm simulation visualization which incorporates a more realistic 3D dynamic model.



A Swarm of Heterogeneous UAVs. The red lines between agent are active communications. The target engagement and detection rings are shown in red. The blue rings are the engagement and detection rings of the UAVs. The numbers are the respective agent strengths.

Bio-Inspired Self Organized Swarms of Unmanned Aerial Vehicles for Attack

Capt Dustin Nowak's research effort explores the possibility of creating Self Organized Swarms of Unmanned Aerial Vehicles (UAVs) that are capable of concerted attack strategies that are bio-inspired. The sequence of events leading to, and through, target engagement, forms a Partially Observable Markovian Decision Process. Through this model, the system can instantiate and select appropriate policies that facilitate self organized target engagement. The previously developed Swarmfare Simulation allows for exploration and generation of the solution space of the rules needed to accomplish this task. With rigorous definition of Self Organized rules and Evolutionary Algorithms to define the rule weighting, the system should successfully engage target sets in a myriad of situations. Results are validated in part through visualization of the Swarmfare simulation.

Both research efforts are co-sponsored by AFIT's Advanced Navigation Technology Center and the Air Force Research Labs.

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Engaging a Moving Target with a Micro Air Vehicle (MAV)

Operational lessons learned from OPERATION ENDURING FREEDOM (OEF) and OPERATION IRAQI FREEDOM (OIF) have demonstrated a need for teams on the ground in urban environments to have the ability to engage time-sensitive targets in real-time, from Non-Line-of-Sight (NLOS) positions without waiting for air support or other direct fires.

Currently, engaging these NLOS targets requires coordination of orbiting assets such as fighter or bomber aircraft, Hellfire missile-equipped Predator UAVs, or joint ground-based artillery systems. While devastatingly effective, these systems have three drawbacks: 1) they must be on-station and available for tasking at the time of the request; 2) they have a high probability of causing significant collateral damage; 3) if available, it often takes time to pass the target information and receive clearance to engage the target – an unacceptable delay when engaging a moving target.

While man-portable weapon systems can overcome these drawbacks, current systems require the operator to have unobstructed Line-of-Sight (LOS) to the target at relatively close ranges. Maintaining an unobstructed LOS in an urban environment, while staying behind protective cover, is challenging at best. These current weapon systems also require the operators to partially expose themselves; this gives away their location and exposes personnel to enemy fire. In addition, these weapons are essentially large, explosive bullets with no loiter or wait capability. Furthermore, if the target moves, or the ground team is re-directed, their response time is significantly increased due to the need to stay covert while navigating through an urban environment.

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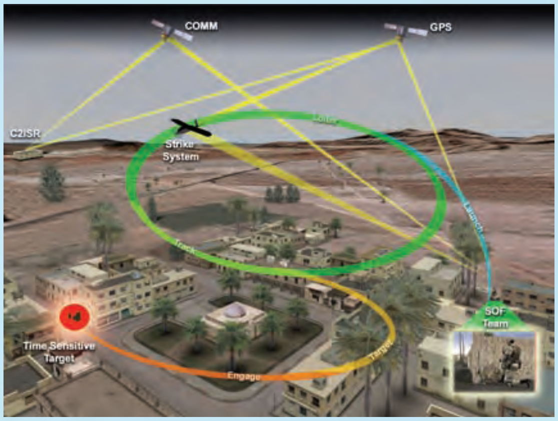

A research team at AFIT completed a systems engineering analysis in March 2007 that identified a Micro Air Vehicle (MAV) as the best platform to provide a self-contained capability for ground forces to track and engage a target. Unfortunately, there is currently nothing in the US or allied inventory that meets the desired capabilities, so the research team developed a roadmap to transition such a MAV to the warfighter. Included in the roadmap are the technical risks that need to be addressed during the development of a MAV in order to provide the desired capability.

Guided by the findings of the previous AFIT team, an ANT research team of five students and four faculty members is working to develop a MAV with the desired capability that would allow the warfighter to covertly launch, loiter, track, positively identify, and engage a target from a safe NLOS position. The system being developed could be effective in urban environments as well as desert, maritime, and temperate environments. Currently, the team is focusing its efforts on the high risk technical challenges identified by the previous group regarding guidance, navigation, and control. Specifically, they are developing the control systems required to track a moving "stop-and-go" target in an urban environment using a MAV.

Some of the current work includes:
- Providing an operator interface that is easy to understand and use.
- Developing a guidance and control system for the MAV that accounts for the wind and that is able to keep the target in view even when the target travels slower than the MAV's stall speed.
- Developing an autonomous relay MAV that provides continuous communication with the tracking MAV, even when there is not a direct line of sight.
- Validating their progress with flight tests/demonstrations.

New Cyber Warfare Program Initiated at AFIT

In December 2005, the Air Force launched a new mission statement stating that we would “deliver sovereign options for the defense of the United States of America, and its global interests – in air, space, and cyberspace.” Since that announcement, the AF has begun to organize, train, and equip a force that can effectively operate in and through the cyberspace domain. Given AFIT’s success in delivering high quality, leading edge education and research in cyber security, it is only natural that we lead the way in educating officers for this new mission area.

One example of our leaning forward is the establishment of the Cyber Warfare program for select Intermediate Developmental Education (IDE) students, beginning with the Summer 2007 term. IDE students are majors who have been designated in the top 20% of their year group. The purpose of IDE is to enhance the professional military competence of Air Force officers through a program of education designed to broaden perspectives, increase knowledge and prepare officers to assume higher levels of command and staff duties and responsibilities. Most IDE students attend Air Command and Staff College or the sister service staff colleges. However, a small cadre (10-20 per year) will be vectored to AFIT for a more technical program in cyber operations and warfare. This program is designed to develop technical and leadership expertise, as well as stimulate creative thinking about employment of cyber power to achieve national and military objectives. In many ways, we are attempting to recreate the energy, creativity, and enthusiasm of the Air Corps Tactical School at Maxwell AFB during the 1920s when air power was in its infancy.

Avoiding Friendly Fire Incidents

Another major thrust within the Center for Systems Engineering has been to support the Core Process III initiatives within the Air Force Research Lab (AFRL). These initiatives look to accelerate support to the warfighter by combining mature technologies in useful concepts that can be rapidly prototyped and demonstrated to support urgent needs. An example of this is the recently completed effort to demonstrate and evaluate friendly marking devices to avoid friendly fire incidences while conducting close air support missions. AFIT students provided the Systems Engineering analysis and test planning as part of a cross directorate effort in AFRL. The group evaluated and tested a wide range of devices, and selected the most promising candidates based on user validated needs.

For the purposes of this program, cyberspace is defined as the electronic realm in which information is stored, processed, and transmitted, to include computer networks and equipment, storage media, and free space. It includes the electromagnetic spectrum and is not just “the network”. Our program covers a wide variety of disciplines spanning technical and non-technical aspects, to include the following:

- Influence operations, psychological operations, and deception
- Communications networks and security
- Electronic warfare and countermeasures
- Threat / vulnerability assessments and risk management
- Legal / ethical aspects of cyber warfare
- Strategic and tactical planning for cyber operations and warfare

USAF IDE programs are limited to 12 months in duration. The AFIT cyber warfare program consists of 40 hours of coursework and 8 hours of research. The research project is normally broad in scope and is focused on a particular problem of interest to Air Force and/or DoD cyber operations community, to include the 8th Air Force at Barksdale AFB LA; the 67th Network Warfare Wing and Air Force Information Operations Center at Lackland AFB TX; the National Security Agency; and US Strategic Command.

The target population for the AFIT Cyber Warfare IDE program includes officers from communications and information, intelligence, flying operations, electronic warfare, operations research, and engineering. The program is also open to sister service and civilian personnel.

AFIT Low Observables Program Touches the Flightline

The AFIT Low observables (LO) program has been ingrained in AF stealth programs for 30 years in both education and research. Our graduates fill critical LO positions in R&D, OT&E including flight test, intelligence across DoD, and various staff and operational units. One reason for our continued success is that our research program focuses on current problems in the LO community. For example, a critical enabler of LO technology is radar absorbing material (RAM), but RAM also presents the biggest challenge to keeping the F-22, B-2, F-117 and other LO platforms mission ready. AFIT recently developed a simple waveguide probe to quickly inspect and characterize material coatings on stealth aircraft. Now, flightline maintainers can potentially diagnose the RAM health of stealth aircraft in half the time and with better precision to significantly reduce maintenance costs and improve aircraft operational availability.

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Combat Modeling for Homeland Defense

The Center for Operational Analysis continues its combat modeling research and analysis using models from the Air Force Standard Analysis Toolkit (AFSAT). A current effort is using the mission level Extended Air Defense Simulation (EADSIM) to model and analyze the capabilities of DARPA's High Energy Liquid Laser Area Defense System (HELLADS). The goal of the HELLADS program is to develop a High Energy Laser (HEL) weapon system on the order of 150 kW light enough to be carried on a tactical fighter platform. This ongoing study uses the HEL modeling capabilities in EADSIM to examine a Homeland Defense scenario incorporating the use of a projected HELLADS capability. Atmospheric propagation of the HEL weapon is modeled using detailed propagation tables generated using the AFIT Center for Directed Energy's High Energy Laser End-to-End Operational Simulation (HELEEOS).

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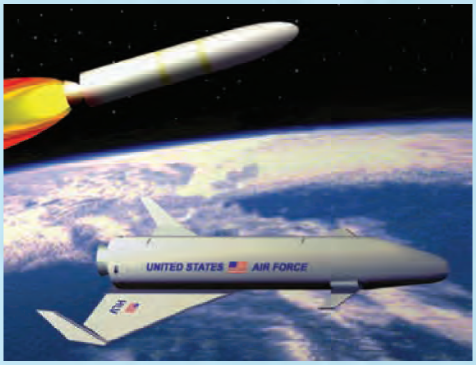
Reusable Launch Vehicles

The Air Force uses a family of expendable launch vehicles to meet its spacelift needs. Unfortunately, this method is not responsive: months of preparation are typically required and operations costs are high. Consequently, the Air Force seeks an affordable, reusable military launch vehicle (RLV) that can be launched and quickly regenerated between sorties. As part of the Operationally Responsive Space initiative, AFRL is sponsoring AFIT research into developing a method for evaluating the life cycle impact of RLV design decisions on the associated ground support infrastructure, personnel, and logistics activities necessary to regenerate an RLV between flights. We first developed a conceptual flow of RLV recovery, maintenance, and integration actions from current ground support processes for the shuttle, military aircraft, and existing expendable launch vehicles, and validated this flow with a Delphi panel of 20 senior experts from NASA, AFRL, Air Combat Command, Air Force Space Command, and the Aeronautical Systems Center. We then used the conceptual flow to build a discrete event simulation model and to estimate the logistics workforce required to support an RLV fleet. Our current research focuses on modeling support activity times as parametric functions of key vehicle design variables.



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Modeling and Analysis to Support Information Operations

While war has always been diplomacy taken to a different level, modern technology, networked interconnectivity, and the ability of technology followers to skip generations has created an increased need to consider the integration of diplomatic, information, military and economic (DIME) strategies executed in the technologically enhanced battlespace with its political, military, economic, social, information and infrastructure (PMESII) functional dimensions. Evolving doctrine suggests that Information Operations in this enhanced battlespace is a component of the military element of national power that contributes to strategic influence where influence is the art of letting some one else have your way. To aid in meeting this evolving challenge, the Operational Science Department at AFIT has been involved in developing modeling and analysis in direct support of a wide spectrum of information operations considerations. These efforts include, but are not restricted to, courses of action evaluation models, information assurance modeling and assessment, social and behavioral modeling, kinetic and non-kinetic targeting models in the physical, social, and cyberspace, stability operations, and influence modeling for a broad array of agencies, commands and task forces.

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Fusion of Automatic Targeting Systems

The Information Fusion Research Group in the Department of Mathematics and Statistics is actively investigating methods to improve the performance of Automatic Targeting systems that require detection, identification or recognition. Information Fusion is a general area of research that includes sub-areas like sensor-, data-, feature-, classifier-, decision-, and label-fusion. We have applied modern mathematical theories to show that an ATR designer can take legacy systems and design a new fused system virtually, that is, choose a combination rule then compute (predict) the performance of the new system without having to physically build it, test it, and measure its performance. The mathematics allows the designer to play "what if" scenarios like changing the performance criteria or combination rule. This allows the designer to choose the best combination of the legacy ATR systems and tells how to fuse them into a single superior ATR system. Real applications include current weapon systems, detection systems at airport security points and chemical classification systems. Employing modern mathematics and information fusion methods for legacy ATR systems will create new weapon systems with better performance, thus keeping the United States air war-fighters the best on the planet.

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Civilian Students Attend AFIT with Support from the Dayton Area Graduate Studies Institute (DAGSI)

DAGSI is a consortium of graduate engineering schools at the Air Force Institute of Technology; the University of Dayton, a private institution; and Wright State University, a state-assisted institution. With funding from the State of Ohio, DAGSI makes scholarships and research fellowships available to graduate students enrolled in engineering/computer science degree programs at its member institutions. 47 students attended AFIT on DAGSI scholarships during FY07, and will be well prepared to support defense-related research and acquisition initiatives as federal or contractor employees upon graduation.

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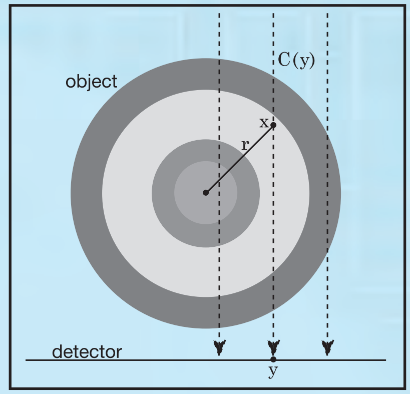
Quantitative Object Reconstruction using X-Ray Tomography and Mixed Variable Optimization



Researchers at AFIT and Los Alamos National Laboratory are applying rigorous derivative-free optimization algorithms in a novel way to the problem of quantitative object reconstruction. Given an object with a low-dimensional parametric description, the goal is to obtain complete geometric details and material compositions from a single x-ray radiograph and in a relatively short time. Existing methods either fail to produce a complete geometric description or take much too long to compute. The new approach involves the formulation of a mixed variable optimization problem (a combination of continuous and categorical variables), which is then solved using the Audet-Dennis Mixed Variable Pattern Search algorithm. In the initial study, which focused on cylindrically symmetric objects with concentric material layers, the number and types of layers and the thicknesses of each layer were found (within a certain tolerance) in 15 of 16 test objects, despite having poor starting points. These promising results have implications for homeland security applications, such as cargo screening.

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Medical Triage for Homeland Security Nursing

AFIT has received an FY07 Large Award in the amount of $335,341 from the Air Force Surgeon General's office to partner with the University of Tennessee – Knoxville (UTK) College of Nursing. AFIT sponsored a CBRN (Chemical Biological Radiological and Nuclear) emergency response project symposium. The content covered existing protocol available for nurses, particularly from the Homeland Security Nursing perspective. Notable attendees included presenters Dr Mark Gebhart from Wright State University and Dr Susan Speraw from the University of Tennessee. Dr Amit Bhattacharya, a topic expert from the University of Cincinnati was also in attendance. Some specific issues being addressed are Emergency Protocol for nurses and physicians, Air Force Instructions for emergency medical response, and TTP (Tactics, Techniques, and Procedures) available as operational guidelines for triage protocol. AFIT and UTK are also collaborating on a technical review on Personal Digital Assistants that can be used to transmit medical data during medical emergencies.

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Particle Image Velocimetry with CO2

Flow visualization and particle image velocimetry (PIV) are very valuable tools for experimental aerodynamics studies. However, implementation of these techniques requires that seed material be injected into the flow, and the undesirable qualities of the seeding material often prevent the use of these techniques in many test environments. This is particularly true for large-scale, closed circuit tunnels where the injected particles remain in the circuit. Facility operators must weigh the risks of tunnel contamination, sensor damage, and safety concerns which might be brought about by the introduction of seed particles. Identification of a practical seeding material that minimizes or eliminates these concerns would allow flow visualization and velocimetry techniques to be deployed in many wind tunnels. We have explored a new concept that is based on the production of particles using carbon dioxide which solidifies as it expands from a high pressure tank. These residue-free particles introduced in the stagnation chamber can provide sufficient seed material in the test section to perform PIV measurements. The technique was applied first in the AFIT small scale supersonic tunnel facility. A single image using this approach to particle seeding is shown in the figure in the wake region of a cone in a Mach 3 flow (right to left). Upon the collection of several image pairs, the velocity profile in the wake was computed and compared favorably with theory. AFIT researchers are currently studying ways to better control the particle size.

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Remote Sensing of Battlespace Detonations for Event Classification

The fireballs resulting from the detonation of conventional military munitions and improvised explosive devices (IED's) produce strong, rapidly changing, emissions in the visible and infrared spectral regions. AFIT's Center for MASINT Studies and Research is working to collect and exploit these spectral signatures for battlespace characterization. In particular, we have developed techniques for the classification of high explosive material type and weight from fielded remote sensors, including high speed Fourier Transform Infrared (FTIR) Spectrometers, multi-band imagers, and radiometers. Our Remote Sensing Laboratory will soon include the nation's first mid-wave, large format, imaging FTIR system, which will explore the complex physical phenomenology of detonation fireballs, muzzle flash, missile plumes, engine exhaust, and smoke stack emissions.

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Atmospheric Effects on Weapons System Performance

Faculty in the Engineering Physics Department and the Center for Directed Energy has developed industry-leading atmospheric effects modeling and simulation, and operational decision aid tools. These tools enable the evaluation of uncertainty in weapon system performance by incorporating probabilistic climatological data or real-time numerical weather information into the first-principles calculations that describe most major atmospheric effects. While originally developed to quantify propagation performance of high energy lasers and high power microwave devices, evolving software tools such as the Laser Environmental Effects Definition and Reference (LEEDR) have been used to assess or improve the operation of a wide range of military systems including the Joint Precision Air Drop System (JPADS) and the transport and dispersion models within the Hazard Prediction and Assessment Capability (HPAC) code. The LEEDR package enables the creation of vertical profiles of temperature, pressure, water vapor content, optical turbulence, and atmospheric particulates and hydrometeors for thousands of land/ocean sites worldwide at line-by-line resolution from the ultraviolet to radio frequencies. Additionally, LEEDR includes a probability of cloud free line of sight (CFLOS) database for air-to-air, air-to-surface, and surface-to-air (or space) look angles that can be produced from probabilistic climatology, historical reanalysis grids, or real-time forecast models.

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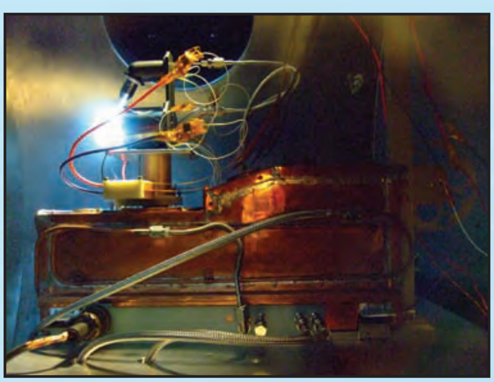
AFIT SPASS Lab Achieves "(AF) Blue Glow"



The Air Force Institute of Technology's newest laboratory, the Space Propulsion Analysis and System Simulator (SPASS), has just reached a major milestone. The inside of the two meter diameter vacuum chamber is currently glowing a distinctive Air Force blue. This characteristic blue glow is produced when a Hall Effect Thruster ionizes xenon gas. One of the major advantages of the Hall Effect Thruster or HET is the high "fuel economy". It requires less fuel to produce the same level of thrust when compared to a more traditional satellite thruster or spacecraft engine. The primary purposes of HETs are helping to keep the satellite in place over a particular point on the earth, and helping to move the satellite to a new position when necessary. Better understanding the limits of the thrusters gives satellite operators valuable information on the capabilities of their spacecraft.

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Dr. John F. Raquet
2006 John L. McLucas Basic Research Award

Dr. John F. Raquet, Associate Professor and Center Director, Advanced Navigation Technology Center, is the recipient of an Honorable Mention for the United States Air Force 2006 John L. McLucas Basic Research Award. The award was presented at the United States Air Force Academy in October 2007. The award recognized Dr. Raquet's pioneering research in the area of non-GPS precision navigation. He has an extensive background in navigating using GPS, but over the past few years his efforts have focused on ways to obtain GPS-level navigation quality when GPS is not available. A gifted researcher, Dr. Raquet has assembled a group of 19 faculty members, 5 staff, and over 40 students, to conduct basic research advancing state-of-the-art navigation technology. The phenomenal success of Raquet's efforts led directly to the creation of the Advanced Navigation Technology (ANT) Center in Fall 2005. The visibility that he has earned makes Dr. Raquet the technical "expert of choice" for many DoD agencies – further advancing AFIT's mission of supporting, and even driving, Air Force basic research.

Dr. Michael Temple Promoted to Full Professor

Dr. Michael A. Temple joined the AFIT faculty in 1996 as a military professor and transitioned to civilian faculty in 2000. In October 2007, Dr. Temple was promoted to Full Professor of Electrical Engineering. Dr. Temple has published 23 journal articles and 49 conference publications in the areas of radar and communications. Of particular note, Dr. Temple received the 2006 AFRL Chief Scientist Award in recognition of the best paper published in a refereed journal having direct and immediate applicability to the AFRL mission. Through Dr. Temple's supervision and mentorship, 5 Ph.D. and 41 MS students have completed their degrees at AFIT.

Dr. Robert F. Mills
2007 Professor Ezra Kotcher Award

Dr. Robert F. Mills, Assistant Professor of Electrical Engineering is the recipient of the Professor Ezra Kotcher Award; in recognition of his advanced curricula development and educational innovation. During the 2006 award period he has made groundbreaking progress in the development of an education and training model for cyber operators. After crafting this model, Dr. Mills presented it to key stakeholders in the newly established Cyber Command at 8th Air Force as well as the 67th Network Warfare Wing, paving the way for Air University to designate AFIT as the lead for cyber education in Air University. Despite the demanding workload of standing up cyber operations education, Dr. Mills has continued his scholarly research, co-authoring eight archival papers, one book chapter, two magazine articles, and sixteen conference papers on a diverse range of topics. He was awarded two Cyber Operations grants from National Security Agency and the AF Information Operations Center and won an AFRL Sensors Directorate $30K innovative research award to study electronic warfare in urban terrain.

Dr. Richard A. Raines Receives 2007 Colonel Charles A. Stone Award

Dr. Richard A. Raines, Professor of Electrical Engineering and Director, Center for Cyber Research (CCR), was awarded the Colonel Charles A. Stone Award; this award recognizes outstanding contributions in cutting-edge research and education, as well as his technological leadership abilities. Through Dr. Raines's efforts, AFIT anticipated the Air Force's need for cyberspace expertise years before cyberspace was included in AF mission statement. CCR has been designated a Center of Excellence by NSA, DHS, and NSF. In 2006, Dr. Raines garnered $1.3M in research funding and his total funding now exceeds $6.4M from 40 different grants. Dr. Raines' work is nationally recognized. He published 5 journal articles and 14 fully refereed conference papers in 2006, bringing his total publication list to an impressive 28 journal articles and 53 conference papers. He mentored and graduated 3 MS students last year, and an additional 4 MS and 4 Ph.D. students continue to work under his guidance.

Faculty Focus

New Department Head
Dr. Jeffery Cochran
Begins Stellar Career
at AFIT

Dr. Jeffery Cochran joined AFIT on July 2, 2007 as head of the Department of Operational Sciences. He was previously on the faculty of the Industrial Engineering Department at Arizona State University for 20+ years where he achieved the rank of Full Professor in 2000. Dr. Cochran received his Ph.D. at Purdue University in 1984 (Industrial Engineering - Operations Research). His research and teaching interests focus on optimization of stochastic models of large-scale entity-flow systems including high technology manufacturing, hospital, transportation, and supply chain systems. His industrial experience includes Battelle Northwest Labs, the Los Alamos National Lab, NASA's LARS Lab, and dozens of funded research projects. He is an author of over 100 scholarly publications, has received ten teaching and advising awards, and serves on four journal editorial boards. He spends weekends doing research with his kids climbing over him.

New Professor

Dr. Jonathan T. Black is an Assistant Professor in the Department of Aeronautics and Astronautics in the Graduate School of Engineering and Management. He received a Bachelor of Science in Industrial Engineering from the University of Illinois at Urbana-Champaign; a Master of Science in Mechanical and Aerospace Engineering from the Joint Institute for Advancement of Flight Sciences, a joint NASA Langley Research Center and George Washington University research program; and recently completed his Doctorate in Mechanical Engineering at the University of Kentucky.

Since coming to AFIT in January 2007, Dr. Black has been given opportunities to serve as AFIT's American Institute of Aeronautics and Astronautics (AIAA) Faculty Advisor and Ohio Space Grant Consortium Executive Committee Member. Through these positions he hopes to encourage student participation in the professional societies by supporting events sponsored by the local sections, assist students in attending and presenting at conferences, and generally promote the students' professional recognition and exposure for their high-quality research work while at the same time increasing the public and professional profile and visibility of AFIT.

Dr. Black is part of a team of ENY faculty that has recently begun collaborating with the Department of Astronautics at the US Air Force Academy (USAFA), resulting in two visits to USAFA by AFIT faculty and one visit to AFIT by the USAFA Astro deputy department head. The collaboration focuses on testing and building models of the department's two capstone design projects: a micro-satellite and a sounding rocket. Dr. Black's other research interests include developing new experimental techniques for testing lightweight deployable aerospace structures and modeling those structures. Additionally, he is part of ENY efforts to redesign the simulated satellite test bed and build a roadmap to launch an AFIT-built payload or micro-satellite.

Dr. Peter S. Maybeck
2007 General Bernard A. Schriever Award

Dr. Peter S. Maybeck, Professor Emeritus of Electrical Engineering, was recently selected as the winner of the General Bernard A. Schriever in recognition of his 34-year tenure at AFIT and his research excellence, teaching enthusiasm, and faculty mentorship. He is responsible for the graduate sequence in estimation and stochastic control and for individual advanced digital filtering and control courses. He has authored over 140 papers on applied optimal filtering. Dr. Maybeck advanced the field of Estimation and Control by authoring and publishing the book, Stochastic Models, Estimation and Control (Academic Press, Vol. 1 - 1979, Vols. 2 and 3 - 1982; republished by Navtech in 1994 and 2001). The timeless value of this book was recognized by being republished after 12 years, and again after 19 years, of the original publication. Current research interests concentrate on using optimal estimation techniques for guidance and navigation systems, tracking, adaptive systems and failure detection purposes. He joined the AFIT family in June 1973, when he was hired as an Instructor in Electrical Engineering; in May 1974, he was appointed as an Assistant Professor and in January 1977 as an Associate Professor in the Graduate School of Engineering and Management. In July 1979, he was appointed Professor of Electrical Engineering, a position he held for 28 years until his retirement on 3 October 2007. Dr. Maybeck's tenure at AFIT was distinguished, a fact proudly reflected in his current status as Professor Emeritus.

Using Dynamic Soaring to Explore Mars

In an effort to advance the state-of-the-art in soaring for full size aircraft, the Air Force Institute of Technology, in collaboration with United States Air Force Test Pilot School (USAF TPS), the National Aeronautics and Space Administration Dryden Flight Research Center (NASA DFRC), and the Air Force Research Laboratory Aerospace Vehicles Technology Assessment and Simulation Branch (AFRL/VACD) launched an effort to demonstrate the energy benefits of dynamic soaring for manned sailplanes.

This project was the first of its kind to show that manned sailplanes could extract energy from horizontal wind shears. Extensive modeling, optimization, and simulation built a solid foundation upon which to conduct flight tests. As a result, the flight test program was a resounding success as all test points were flown and all objectives were met. The flight test results were in accordance with dynamic soaring theory and closely matched those predicted by dynamic optimization and simulation. This effort laid a foundation for dynamic soaring with full size aircraft on which future research can be conducted using different types of wind shears, different classes of sailplanes, and different maneuvers. The results of this project are featured in the PBS program Nature - Raptor Force, which premiered on 18 February 2007

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Cooperative Autonomous Navigators for Intelligent Sensing (CANIS)

The CANIS project seeks to develop an autonomous robotic, network-enabled, Search, Track, ID, Geo-locate, and Destroy (Kill Chain) capability effective for any environment, at any time. The mechanisms behind this require research into cooperative sensing capabilities in GPS degraded areas. There are two objectives of this project, the development and theory behind autonomous individual and multi-robot control, and research into robust guidance, navigation, and control (GNC) architecture for non-GPS environments. In developing autonomous multi-robot control and coordination algorithms, we conduct research in the system of systems components that make up hybrid and three layer robot control architectures, and adding the coordination and coalition formation components to create the collective multi-robot case. For the non-GPS navigation, we investigate the applicability and fusion of disparate noisy sensors in order to provide navigation information. More specifically, we combine MEMS based inertial units, image aided navigation, simultaneous localization and mapping, and 3-D ladar shape based techniques.

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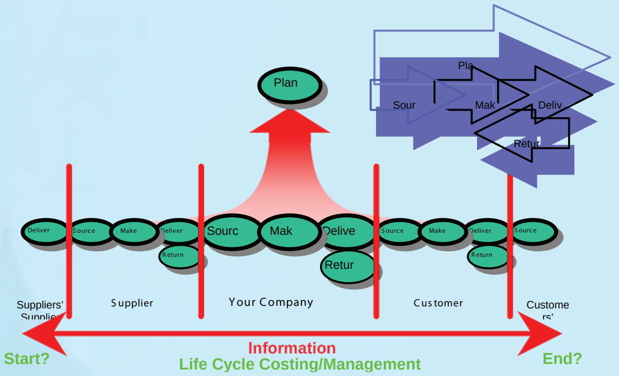

Supply Chain Operations Reference Model (SCOR)

Graduate Certificate in Supply Chain Management

The Department of Operational Sciences (AFIT/ENS) announces a new Graduate Certificate in Supply Chain Management. The purpose of this certificate is to provide students with graduate level education in the fundamentals of Supply Chain Management (SCM) with particular emphasis on Department of Defense (DoD) and Air Force specific applications. Lean operations related to Air Force Smart Operations for the 21st Century (AFSO21) are emphasized. Statistical data analysis and quantitative modeling including linear programming, simulation analysis, and heuristics are applied to the SCM setting. The certificate is offered via distance learning and is available to DoD and private sector personnel. The certificate objective enables students to apply state-of-the-art analytical and problem solving techniques to Air Force and DoD specific supply chain management problems, and utilize the concepts of lean. Holders of the certificate will be qualified to fill positions in supply chain management including transportation, purchasing, and inventory management. At completion, students will understand how the functional areas that comprise the supply chain interact with one another, in both the defense and private sectors.

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AFIT Conducts Joined-Wing Aircraft Test in Partnership with International Consortium

LtCol Vanessa Bond conducted wind tunnel testing at the Portuguese Air Force Academy (POAFA) as part of an international collaborative effort to investigate a joined-wing sensorcraft configuration. The project, sponsored by the Air Force Research Lab Air Vehicles Directorate and Air Force Office of Scientific Research, explored a joined-wing design created by Boeing for AFRL (see fig. 1) that potentially provides more surface area for wing-mounted sensors than conventional aircraft designs. Just as the A-10 Thunderbolt II was built around the 30 mm gun, this future uninhabited aerial vehicle (UAV) is designed around the required sensors. In the past, most sensor platforms have added the sensors to an existing aircraft. This new approach will employ a composite skin specifically designed to incorporate the sensor into it. As part of AFIT's contribution to the sensorcraft initiative, LtCol Bond investigated the possibility of twisting the aft wing to control pitch, much like the Wright brothers employed wing warping of their cloth wings to maneuver. However, rather than dealing with wires and cloth, the UAV will have an aeroelastic load-bearing structure. Using a 1/38 scale aerodynamic model in the tunnel at the POAFA laboratory, LtCol Bond measured the aerodynamic forces required of the joined wing, such that an appropriate pitch control mechanism could be realized. Her results will contribute to the ultimate goal of correctly modeling the mass and stiffness characteristics of the full-size aircraft.

LtCol Bond completed this doctoral research under the advisement of Dr. Robert Canfield. The Portuguese Air Force Academy provided outstanding hospitality for LtCol Bond's participation in this consortium effort, which also involved researchers from the University of Manchester, UK.

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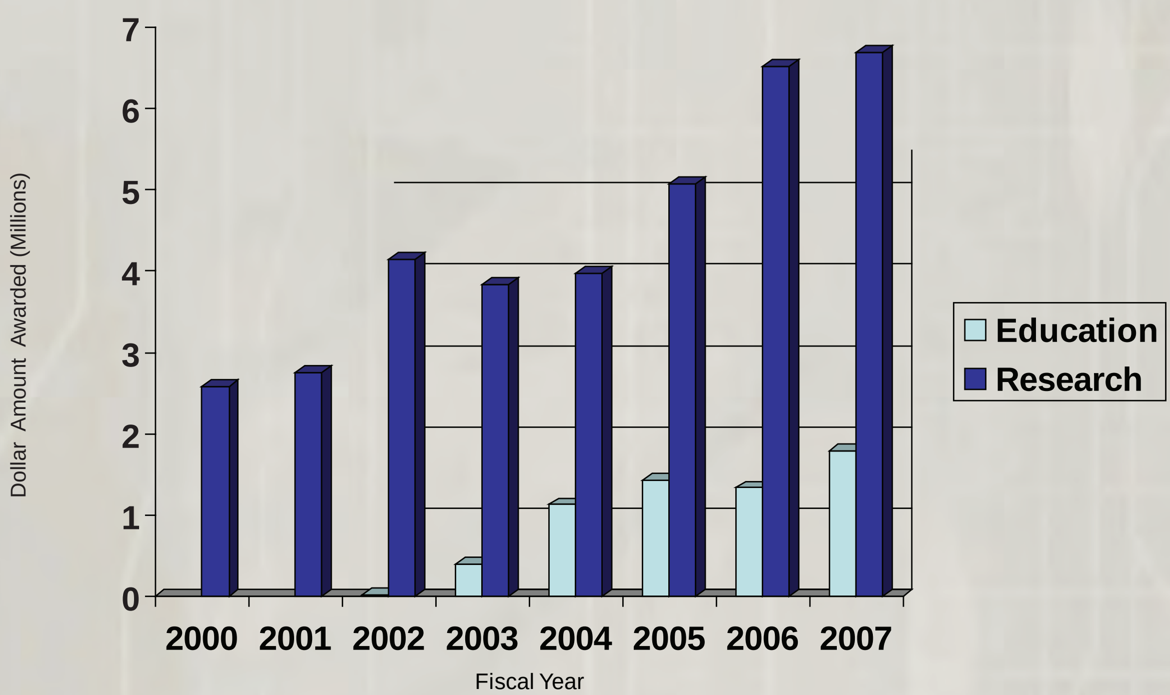
New FY07 Awards to Academic Departments & Research Centers by Type

	Research		*Education*		*Total*	
Department	*#*	*Dollars*	*#*	*Dollars*	*#*	*Dollars*
Mathematics & Statistics (ENC)	4	68,979	-	-	4	68,979
Electrical & Computer Eng (ENG)	52	2,241,268	5	1,090,018	57	3,331,286
Engineering Physics (ENP)	34	2,316,659	3	548,922	36	2,865,581
Research & Sponsored Programs (ENR)	1	10,201	-	-	1	10,201
Operational Sciences (ENS)	16	388,825	-	-	16	388,825
Systems & Eng Management (ENV)	11	644,877	-	-	11	644,877
Aeronautical & Astronautical Eng (ENY)	43	1,014,789	4	150,045	47	1,164,834
TOTAL	**161**	**6,685,599**	**12**	**1,788,985**	**173**	**8,474,584**
Center*						
Advanced Navigation Technology Center (ANT)	25	1,140,390	1	20,160	26	1,160,550
Center for Directed Energy (CDE)	17	1,353,227	2	38,922	19	1,392,149
Center for Cyberspace Research (CCR)	9	390,987	4	1,069,858	13	1,460,845
Center for MASINT Studies and Research (CMSR)	5	357,240	1	510,000	6	867,240
Center for Operational Analysis (COA)	12	343,825	-		12	343,825
Center for Systems Engineering (CSE)	6	215,150	2	109,725	8	324,875
Center for Space Studies and Research (CSSR)	2	97,869	-	-	2	97,869
TOTAL	**76**	**3,893,268**	**10**	**1,748,665**	**86**	**5,647,353**

* All Center funds are also included in departmental funding

New Award History FY00-FY07



Air Force Institute of Technology Research – Large Awards* FY07

Research Data

Department of Electrical and Computer Engineering

Advanced Navigation Technology Center (ANT)

"Advanced Navigation Technology (ANT) Center and Laboratory Support"
$242,000 – Air Force Research Laboratory Sensors Directorate (AFRL/RY)
Principal Investigator: Dr John F. Raquet

"Technical Support: RF- EW Systems"
$100,000 – AFRL Sensors Directorate (AFRL/RY)
Principal Investigator: Dr Michael A. Temple

Center for Cyberspace Research (CCR)

"AFIT Transformation Chair"
$166,700 – Secretary of Defense (SECDEF)
Principal Investigator: Dr Richard A. Raines

"Development of a Federal Cyber Force at the Air Force Institute of Technology"
$510,710 – National Science Foundation (NSF)
Principal Investigator: Dr Richard A. Raines

"Target Discovery, Sensor Fusion, and Mitigation Analysis"
$100,000 – AFRL Sensors Directorate (AFRL/RY)
Principal Investigator: Dr Richard A. Raines

"Tuition and Resource Support for AFIT Center for Cyberspace Research"
$317,448 – National Security Agency (NSA)
Principal Investigator: Dr Richard A. Raines

Other

"Electromagnetic Analysis and Design of Non-Destructive Evaluation Systems"
$100,000 – AFRL Materials and Manufacturing Directorate (AFRL/RX)
Principal Investigator: Dr Michael J. Havrilla

"Remote Sensing and Communications for MASINT"
$100,000 – National Air and Space Intelligence Center (NASIC)
Principal Investigator: Dr Andrew J. Terzouli, Jr

Department of Engineering Physics

Center for Directed Energy (CDE)

"Cryo-Cooled Ti-Sapphire Laser to be Used in DPAL Experiments"
$106,464 – AFRL Directed Energy Directorate (AFRL/RD)
Principal Investigator: Dr Glen P. Perram

"Delivered Irradiance Assessment Tool (DIAT)"
$103,000 – Directed Energy Test & Evaluation Capability (DETEC)
Principal Investigator: Dr Salvatore J. Cusumano

"High Energy Laser Modeling and Simulation Program: TAWG Product Development"
$400,000 – AFRL Directed Energy Directorate (AFRL/RD)
Principal Investigator: Dr Salvatore J. Cusumano

"High Power Diode Pumped Alkali Vapor Lasers and Analog Systems"
$176,450 – High Energy Laser Joint Technical Office (HELJTO)
Principal Investigator: Dr Glen P. Perram

"Technical and Administrative Support for the AFOSR Center of Excellence in High Power Gas Phase and Electric Lasers"
$103,000 – AFRL Directed Energy Directorate (AFRL/RD)
Principal Investigator: Dr Glen P. Perram

Center for MASINT Studies and Research (CMSR)

"Advanced Geospatial-Intelligence Education"
$510,000 – National Geospatial-Intelligence Agency (NGA)
Principal Investigator: Dr Ronald F. Tuttle

"Countering the IED Threat with Infrared Signatures"
$100,000 – Office of the Secretary of the Air Force (SAF/FMBMB)
Principal Investigator: Dr Glen P. Perram

"MASINT Academic Support"
$100,000 – AFRL Sensors Directorate (AFRL/RY)
Principal Investigator: Dr Ronald F. Tuttle

Other

"Role of Water in Heat Inactivation of Bacillus Anthracis Spores and Spores of Related Organisms"
$105,000 – Air Force Nuclear Weapons and Counterproliferation Agency (AFNWCA)
Principal Investigator: Dr Larry W. Burggraf

Department of Systems and Engineering Management

"Development of a Technology Based Medical Triage and Situational Awareness Tool for Use in a CBRN Contingency/Deployed Environment"
$335,341 – Surgeon General (HQ USAF/SG)
Principal Investigator: Dr Adedeji B. Badiru

*Large awards are those that earn $100,000 or more for a single proposal in the given fiscal year.

http://www.afit.edu/de

http://www.afit.edu/cse

http://www.afit.edu/ccr

http://www.afit.edu/ant

http://www.afit.edu/coa

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Sponsoring Thesis Topics

AFIT encourages input from your agency that aligns our research and student education to relevant areas to ensure the technological superiority and management expertise of the U.S. Air Force and the Department of Defense. Each topic submitted has a strong positive impact on AFIT's ability to focus on research relevant to real-world requirements. http://www.afit.edu/en

AFIT Yellow Pages

For specific information regarding faculty and their research areas, please visit: http://www.afit.edu/YellowPages/default.cfm

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