

Graduate School of Engineering and Management
ANNUAL REPORT 2008
AIR FORCE INSTITUTE OF TECHNOLOGY

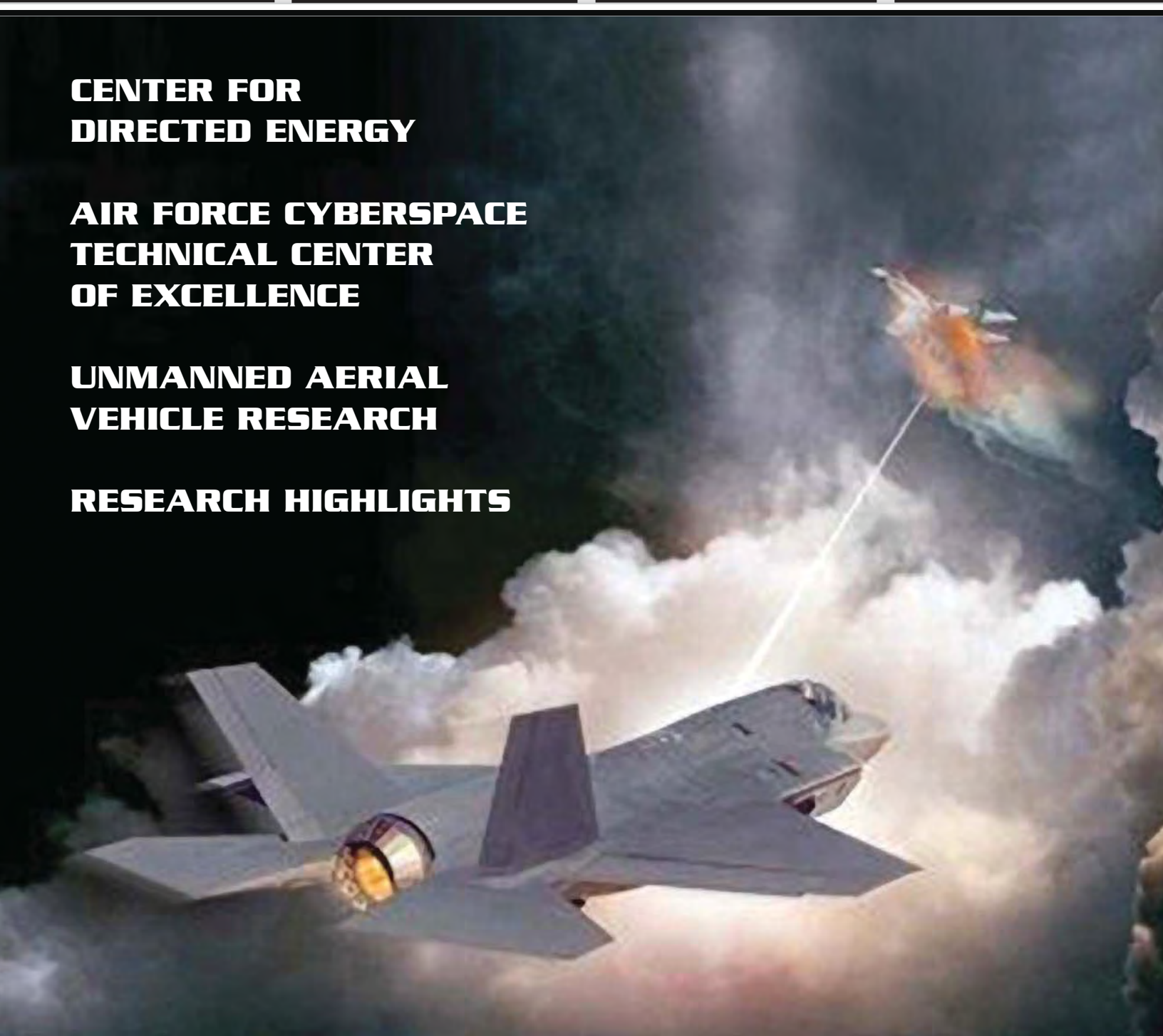


**CENTER FOR
DIRECTED ENERGY**

**AIR FORCE CYBERSPACE
TECHNICAL CENTER
OF EXCELLENCE**

**UNMANNED AERIAL
VEHICLE RESEARCH**

RESEARCH HIGHLIGHTS



AFIT Overview

What started in 1919 as a school for select officers has grown into a premier educational institution for both officer and enlisted students, international students, Department of Defense civilians, 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

The mission of the AFIT Graduate School of Engineering and Management is to provide high-quality graduate education programs and engage in research activities that enable the Air Force to maintain its scientific and technological dominance.

www.afit.edu/en



Dr. Thomas, Dean

Message from the Dean

“Reflecting on the Past... Shaping the Future” was the theme of AFIT’s first Heritage Symposium held in September, 2008. Many prominent alumni shared insights about their military careers and the impact of their AFIT education with our incoming class. The men and women of the Graduate School of Engineering and Management are proud of our alumni’s achievements, and of our role in educating the nation’s future leaders.

This Annual Report 2008 highlights recent research achievements of our faculty and students. An integral component of graduate engineering education, our research is focused on topics that will enable our troops to adapt to emerging threats and apply innovative technologies to maintain dominance in the battlespace.

The Center for Directed Energy (CDE) is the focus of this year’s report, although we have many contributions in nuclear detection and weapons effects, autonomous vehicles, cyberspace, propulsion, non-GPS navigation, and other areas that will be described more fully in future reports. The Center for Directed Energy investigates enabling technologies, including laser development and beam control, and system concepts for Directed Energy Weapons (DEW). These speed of light DEW systems will provide unprecedented options to commanders requiring rapid, controlled effects.

Our faculty, staff, and students are receiving national recognition for their achievements. Most notably, AFIT’s Center for Cyberspace Research was designated the Air Force’s Cyberspace Technical Center of Excellence (CyTCoE). The Center for Directed Energy’s accomplishments were also recognized with the United States Air Force Modeling and Simulation Planning Award.

Even as we reflect on our 2008 achievements with pride, the faculty, staff, and I are working hard to shape the future. We have reinvigorated our strategic planning process to find ways to increase the quality, relevance and quantity of our educational and research contributions. We will continuously strive toward our vision of excellence in defense-focused, research-based engineering and applied science education to better serve our students, the United States Air Force, and our nation.



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



Dr. Salvatore Cusumano,
Director, Center For Directed Energy

The Center for Directed Energy (CDE) performs a mission of research, education, and innovation. The CDE, the first Air Force Institute of Technology Center for Specialized Research, was established within the Department of Engineering Physics in March 2002. The Center for Directed Energy has a diverse research-funding portfolio and continues to expand its customer base. CDE generated over 3.9 million dollars in the last three years in studies and analysis of high energy lasers (HEL) and its enabling technologies. The Center supports a myriad of customers within the research, acquisition and the intelligence communities including: the Air Force Research Laboratory (AFRL); the High Energy Laser Joint Technology Office; the Airborne Laser System Program Office, and the National Air and Space Intelligence Center.

Recently, the Center was awarded the Air Force's Modeling and Simulation Award for Planning. This award recognized the on-going development of a mission planning tool for HEL systems. The Center's research is recognized nationally as

of the CDE is staffed with AFIT employees and supported with post doctoral researchers who are first indoctrinated under the guidance of faculty at AFIT. The focused research is unmatched anywhere in the laser community addressing improvements and understanding gas phased lasers from Chemical Oxygen Iodine to new concepts employing diode-pumped alkali lasers.

The CDE, although resident within AFIT's Engineering Physics Department, includes analysts from across all departments within AFIT. The research is multi-discipline, spanning esoteric studies to broad reaching analysis. Topics include: researching mitigation of aero-optical flow effects on laser propagation; the analysis and implementation of branch point reconstructors; the trade-offs between a self-referencing interferometer and a Shack-Hartmann and the benefits of a hybrid combination of the two; the effects of the boundary layer on tactical laser weapons; the development of analysis tools to predict HEL effectiveness over any territory within the world; the simulation of a given target and environment, to analyze performance of a track algorithm from any one of the three general classes of Centroid, Correlation, or Stochastic; and the remote sensing of combustion constituents using high frame rate imaging Fourier Interferometers.

The CDE believes that its growth and benefit to the community are best achieved through a spirit of collaboration. The CDE is currently teaming with the University of Notre Dame, University of California, University of New Mexico, to name a few. These collaborations have lead to Multi-discipline Research Initiatives spanning three years of funding. The CDE periodically hosts workshops on focused DE topics and continues to provide technical short courses (both on site and over the Web). Recently, the Directed Energy Professional Society funded the development of a companion text book for a previously funded Laser Weapon System Short Course. This course is one of four building up to a graduate certificate program in HEL directed energy. This certificate program will be available in the fall of 2009.

The 12 faculty personnel and 15-20 students, from four

“Let me be the first to predict that the impact of DE weapons will be as revolutionary as the nuclear submarine was to Naval Warfare.”

evidenced by faculty papers regularly being published in peer-reviewed academic and scientific technical journals.

One of the best tributes to the CDE occurred when AFRL Directed Energy Directorate solicited the Center's expertise and leadership in the establishment of the Center for High Power Gas Phase Hybrid Lasers located on Kirtland AFB. This 'child'

departments associated with the Center, have been invited to participate in Department of Defense (DoD) workshops, task forces, safety review boards, conferences, and other arenas where Directed Energy expertise is needed. With a modern laboratory facility of over 6500 sq feet of space, in-house research capability is well supported by AFIT corporate. This continual interaction with

the community is essential to establish the merits of DE and, just as important, for the Center to maintain its competency in providing the most up to date research and solutions.

DE related research plays a significant role in the development of DoD science and technology educational professionals, both officers and civilians. The CDE has also supported the expansion of civilian enrollment at AFIT by hosting summer interns and leveraging DAGSI to attract

civilians to pursue DE related academic degrees.

The articles featured within this annual report are samples of the quality and dedication that the CDE personnel bring to the research, education, and innovation of the science in Directed Energy. "Let me be the first to predict that the impact of DE weapons will be as revolutionary as the nuclear submarine was to Naval Warfare," Dr. Salvatore Cusumano said.

AFIT High Energy Laser Project Team Wins 2007 USAF Modeling and Simulation Planning Award



Award presentation by Brig. General Paula Thornhill to Richard Bartell, Matthew Krizo, and Lt. Col. Steven Fiorino

The Air Force Institute of Technology Center for Directed Energy, an AFIT Center of Specialized Research, was recently presented the 2007 United States Air Force Modeling and Simulation Planning Award. The Air Force Agency for Modeling and Simulation (AFAMS) makes this award annually to USAF teams that have provided outstanding contributions to USAF M&S personnel in support of the warfighter in one of seven areas: Acquisition, Analysis, Training, Cross-Functional, Test and Evaluation, Experimentation, and Planning.

CDE was recognized for its "...unmatched and warfighter focused directed energy weapons performance assessment software available to all DoD services and agencies in joint and coalition environments." CDE has developed two performance models: the High Energy Laser End-to-End Operational Simulation (HELEEOS), and the Laser Environmental Effects Definition and Reference (LEEDR). HELEEOS, developed with support from the High Energy Laser Joint Technology Office (HEL JTO) models laser weapons device performance over a diverse

scope of wavelengths and engagement scenarios. LEEDR, developed by CDE, is a software package that provides numerical and "real time" worldwide atmospheric data inputs into directed energy performance modeling.

The HELEEOS/LEEDR engines have been utilized by the Joint Mission Effectiveness Manual Special Operations community, integrated into Joint Integrated Mission Model, the Navy's joint integrated mission model, and have also been leveraged within the intelligence community to address Directed Energy related technical issues within that community. HELEEOS also possesses capability to predict high power microwave propagation for defending and operating within cyberspace. The Director of the HEL JTO, Mr. Mark Neice, recently highlighted CDE contributions to the tri-service DoD DE community at the 11th Annual Directed Energy Professional Society Symposium.

The broad-spectrum M&S capability of the CDE enables researchers, planners, and operators to address three of the four AF Scientific Advisory Board FY08 topics. HELEEOS predicts high power microwave propagation for defending/operating in the cyber domain and characterizes the environment for airborne tactical laser feasibility. LEEDER's line by line assessment tools permit optimal, all weather spectrum management and exploitation. Members of the CDE team included: Mr. Richard Bartell, team lead, Mr. Matthew Krizo, lead software developer, Steven Fiorino Lt Col, USAF, Dr. Glen Perram, Mr. Daniel Fedyk, Mr. Kenneth Moore, Mr. Thomas Harris, Mr. Christopher Rice, Mr. Mark Houle, ctr, and Dr. Salvatore Cusumano.

**For more information,
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Center for Directed Energy Develops Version 3 of High Energy End-to-End Operational Simulation (HELEEOS)

The High Energy Laser End-to-End Operational Simulation version 3 is a one-on-one engagement model currently under development by the CDE. HELEEOS is one aspect of the High Energy Laser Joint Technology Office's overall modeling and simulation strategy. Requirements for this modeling and simulation capability include capturing the operational requirements, inviting a wide spectrum of analyses, constraining weapon effectiveness through accurate engineering performance assessments, and the establishment of trust among military leaders.

The HELEEOS model is designed to provide reasonable fidelity in predictions of energy delivered to a target over a broad range of engagement scenarios. HELEEOS is capable of modeling high fidelity geometry on a round earth. The geometry model handles laser sources, targets, multiple relays, and an off-axis observer. Also included in HELEEOS is an advance atmospheric effects model including the effects of extinction due to molecular and aerosol effects, cloud and rain models, and several state of the art turbulence models. All of these models can be used for coherent sources for wavelengths between 400 nm and 8.6 m for any location around the world.

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Current users of HELEEOS include:

**Air Force Research Laboratory (AFRL)
Directed Energy Directorate**

AFRL Air Vehicles Directorate

National Air and Space Intelligence Center

United States Military Academy

United States Naval Academy

Naval Postgraduate School

Naval Air Systems Command

Naval Sea Systems Command

**Office of the Secretary of Defense, Program
Analysis and Evaluation**

Johns Hopkins Applied Physics Laboratory

Jefferson Laboratory

Lockheed Martin

Raytheon

Boeing

Ball Aerospace

Modeling of Tactical Directed Energy Weapon System Performance on Worldwide Basis from the Visible to the Radio Frequencies

The Development of a Global Directed Energy Mission Planning Tool

Key-recently introduced features of the Air Force Institute of Technology Center for Directed Energy High Energy Laser End-to-End Operational Simulation parametric one-on-one engagement level model allow it to meet Modeling & Simulation needs and function as a near term mission planning tool. These features include the capability to derive vertical profiles of atmospheric effects based probabilistic climatology, historical weather reanalysis grids, or real-time forecast models available on-line. Each atmospheric gas or particulate is evaluated based on its wavelength-dependent forward and off-axis scattering characteristics and absorption effects on electromagnetic energy delivered at any wavelength from 0.4 μm to 8.6 m. HELEEOS can produce profiles, including correlated optical turbulence profiles in percentile format, from probabilistic climatology for over 400 land sites worldwide for all times of day and for a $1^\circ \times 1^\circ$ grid over all ocean locations. In addition, probability of

cloud free line of sight for hundreds of land sites worldwide is available in the model. Effects of thin layers of fog, several types of rain and several types of water droplet and ice clouds can also be considered. Use of web-based numerical weather data constitutes a step toward the development of a true directed energy mission planning tool. Complex interactions between the effects of meteorological parameters as a function of location, specific time of day, and season on predicted laser system performance have been demonstrated. Use of gridded numerical weather reanalysis data reveals operationally relevant changes in predicted system performance over fairly localized areas, indicating that in many cases conditions exist which might be exploited for operational advantage in employment of directed energy weapons if correctly forecasted and analyzed. The architecture supports any platform-target-observer geometry, geographic location, season, and time of day; and it provides for correct contributions of the sky-earth background.

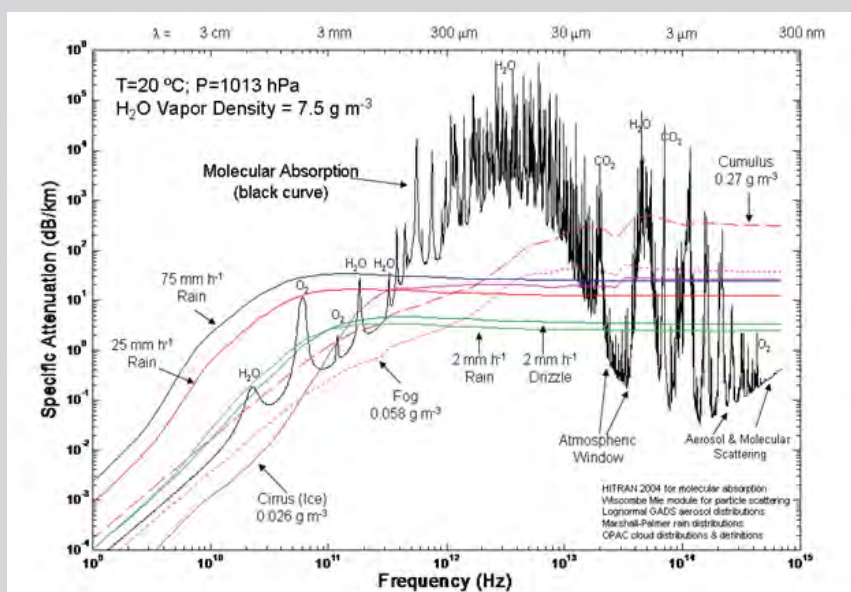


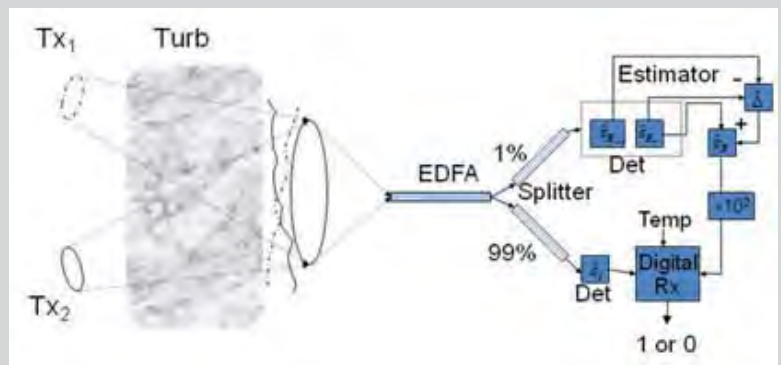
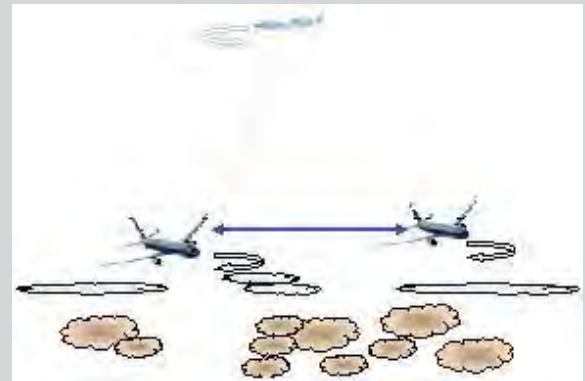
Figure: Atmospheric effects modeling from 0.4 μm to 8.6 m

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Airborne Laser Communications

AFIT researchers have developed an innovative transmitter for high speed, secure, reliable laser communications using multiple low-power lasers. Laser communication systems can provide timely life saving information flow to military commanders and operators through environments that are inappropriate for electrical wires and optical fibers, like transferring data from satellites or to aircraft. Using lasers rather than radio frequencies to transmit voice, imagery, video, and other data can provide extremely high data rates with directional links (rather than broadcasting). However, designs developed through DARPA's Optical RF Combined Link Experiment (ORCLE) and its successor, Optical RF Combined Link Experiment Communication Adjunct (ORCA) face a key technical challenge: compensating for the distorting effects of atmospheric turbulence. If not compensated, atmospheric turbulence causes long, deep signal fades at the receiver. Conventional adaptive optics (AO) and optical automatic gain control techniques have failed to adequately mitigate these signal fades.

AFIT's approach uses multiple low-power lasers at the transmitter instead of AO. The laser beams are sized and arranged in an optimal way, given a turbulence model. The idea is to separate the lasers just far enough apart so that the atmospheric distortions to them are statistically uncorrelated. This way, at least one laser experiences favorable atmospheric conditions at all times, and the received signal fades are extremely rare. When combined with adaptive thresholding at the receiver, the reliability increased 100,000 x.



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Modeling Spectral Remote Sensing of Dynamic Engagements

In support of the Directed Energy Test and Evaluation Capability, AFIT CDE developed a high fidelity simulation, built upon the HELEEOS engine, of a bi-static five channel measurement of irradiance delivered on a distant target. The multispectral example emphasizes the interaction of the high energy laser on target, the observed reflectance, and the subsequent hot spot generated due to heating of the target surface. Particular care is taken in modeling the bi-directional reflectance function of the laser/target interaction to account for both the coupling of energy into the target body and the changes in reflectance as a function of temperature. The simulation accurately models the thermal response, kinetics, turbulence, base disturbance, diffraction, and signal-to-noise ratios.

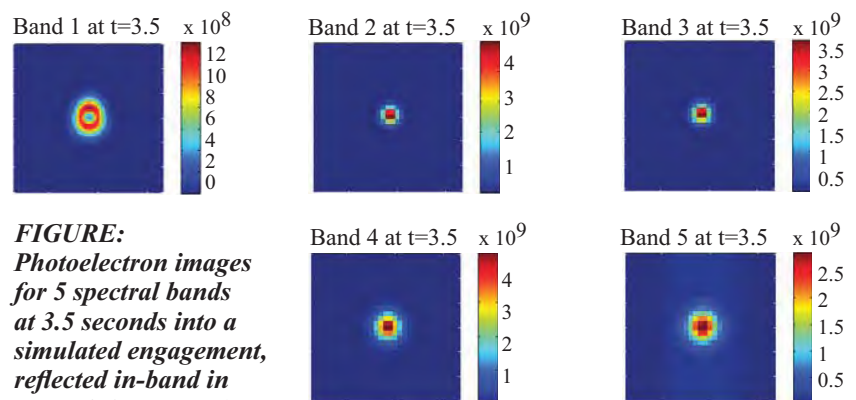


FIGURE:
Photoelectron images for 5 spectral bands at 3.5 seconds into a simulated engagement, reflected in-band in upper left, MWIR 1 upper center, MWIR 2 upper right, LWIR 1 lower left, LWIR 2 lower right

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Development of Laser Source/Tracker Hardware for Inflight Experiment

In 2008 the Air Force Institute of Technology Center for Directed Energy began development of a laser source and associated tracker hardware for use in an inflight experiment in collaboration with the University of Notre Dame. Next-generation and spiral-improved airborne laser systems must be able to mitigate the effects of turbulent air flow around turrets housing the laser, known as aero-optic effects, in order to expand their lethal field of regard. To date no platform exists to flight test for these aero-optics effects.

The objective of this program is to develop economical

flight test hardware to experimentally explore baseline aero-optic effects and test mitigation schemes. The full experiment consists of two Cessna Citations, one with a 12 inch turret for receiving an incoming diverging laser beam through the aero-optical environment around the turret and deliver it to an optical bench onboard the Airborne Aero-Optics Laboratory (AAOL) (Fig 1&2). The second (chase) aircraft has a diverging laser source, developed by AFIT, which will track the AAOL turret with an accuracy better than 50 microradians.

Figure 2: Shown in the CAD rendering is a conceptual arrangement of Airborne Aero-Optics Laboratory equipment inside of a 3D model of a Cessna Citation.

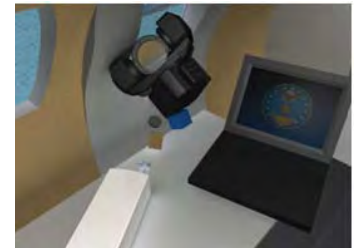


Figure 1: Arrow-Optics flight test configuration

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Portable Terahertz Source Development

A terahertz time domain spectroscopy (THz-TDS) imaging testbed has been developed at AFIT and successfully applied to the imaging of aerospace composites. However, the system is large and not suitable for flight line maintenance. To address this problem, AFIT is developing portable, small footprint terahertz sources. The portable system being developed uses an efficient Cr:LiSAF laser modelocked with a saturable absorbing mirror being provided through a collaboration with the Massachusetts Institute of Technology. The diode pump lasers leverage the development of high power red lasers for the DVD market making them extremely cost effective and efficient. The Cr:LiSAF laser is capable of continuous operation using 8 AA batteries for 8 hours. The pulsed terahertz radiation is generated using a low-temperature grown GaAs photoconductive switch, which requires only 5 mW of optical power to generate terahertz radiation. The pulsed operation enables coherent detection of the THz radiation, which improves the signal to noise over continuous wave systems by over 3 orders of magnitude. In addition, the

coherent detection senses both the amplitude and phase of the THz signal which means both the extinction and optical path length (either thickness or index of refraction) can be measured in a single scan. The initial demonstration of terahertz time domain spectroscopy will require the use of a scanning time delay; however, AFIT plans to use double pulsing of the Cr:LiSAF laser for asynchronous optical sampling, which requires no moving parts. The end system would be extremely robust (no moving parts), portable and battery powered. This system opens a wide variety of Air Force and DoD applications such as aircraft maintenance and the detection of explosives.

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Multipactor Discharge Mitigation ... Preventing Waveguide Window Failure in High Power Microwave (HPM) Systems

A multipactor discharge is an electron avalanche supported by secondary electron emission that can couple the HPM field energy to a waveguide dielectric window. The energy deposition can lead to the destruction of the dielectric material and catastrophic window failure. Understanding discharge formation and coupling permits the investigation of mitigation and suppression techniques. Mitigation approaches were investigated using Particle-In-Cell simulations. Initially baseline susceptibility diagrams were constructed analytically and compared with self-consistent, dynamic system trajectories. Geometric mitigation was then considered by varying the window orientation with respect to the HPM electric field. Small angular deviations, less than 20 degrees, from the nominal

case of the electric field parallel to the surface show dramatic changes in the susceptibility diagram. A materials approach to mitigation was then considered. Titanium Nitride, TiN, coatings applied to the dielectric surface can substantially reduce the secondary emission yield. Representative TiN modifications of the virgin secondary emission yield were simulated and the resulting susceptibility diagrams were assessed in terms of system design implications.

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Modeling State of the Art Laser Systems Comprised of Multiple Tiled Subapertures

Solid state slab and fiber laser technologies are rapidly emerging in the directed energy community. The Air Force Institute of Technology Center for Directed Energy is developing performance models of state of the art laser weapon system configurations consisting of tiled arrays of both slab and fiber subapertures. These performance models are based on results of detailed

waveoptics analyses conducted using WaveTrain. System characteristics which can be evaluated include subaperture shape, aperture fill factor, subaperture intensity profile, subaperture placement in the primary aperture, subaperture piston coherence, subaperture differential jitter, wavefront error associated with each subaperture, and atmospheric path effects.

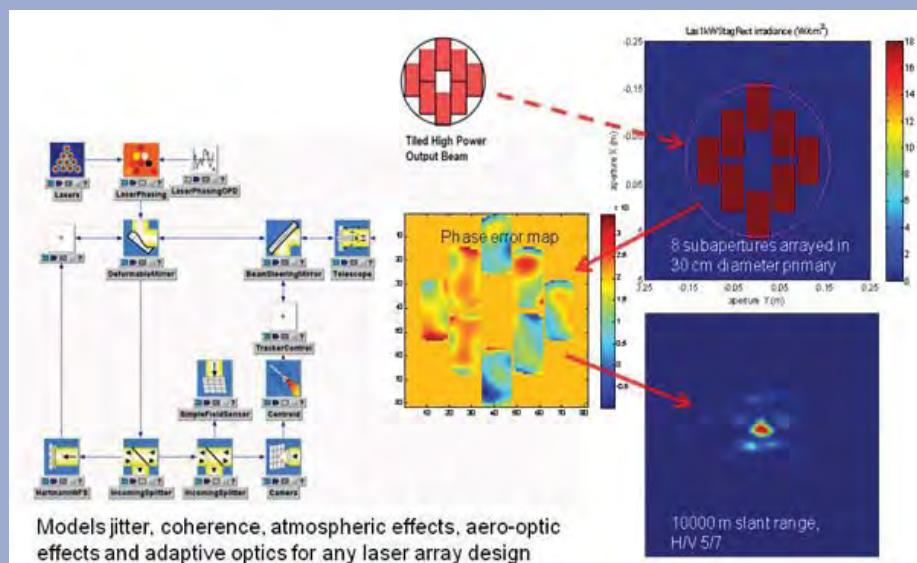
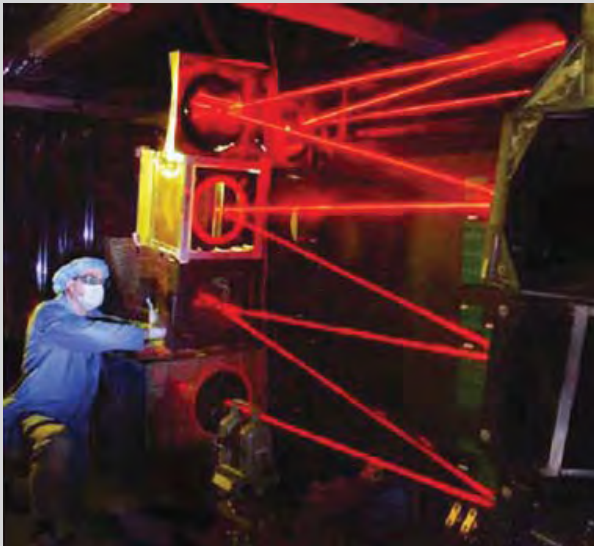


Figure: Waveoptics modeling of a laser system composed of tiled subapertures

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Keeping Directed Energy Education on Target



The Air Force Institute of Technology educational programs in Directed Energy date back to the late 1960's. The programs have evolved as the technology advanced and missions expanded. AFIT faculty have solicited and obtained information from our users and graduates leading to enhancements in programs servicing existing educational codes and the design of new programs. The companion educational program is a joint program of the Department of Electrical and Computer Engineering and the Department of Engineering Physics, recognizing the interdisciplinary nature of Directed Energy technology. The program addresses expanded requirements from the Department of Defense and the Air Force in the High Powered Microwave arena with the increased importance of beam control.

The program focuses the research activities of AFIT students pursuing graduate education with a DE specialization on topics of current interest to the DE community.

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Successful Short Courses offered through AFIT's Center for Directed Energy

An 8 hour short course on High Power Microwaves is offered with a modular approach to the design and characterization of a High Power Microwave system. The objective is to provide an understanding of the system components and the attributes of the weapon system. The weapon system is viewed as consisting of five modules: prime power and power conditioning equipment, a microwave source, structures to couple the source to the propagation media, propagation media, and the target.

The Center for Directed Energy also offers a 32 hour Laser Weapons Systems Short Course. A thorough presentation of High Energy Laser weapon systems is under development for students with undergraduate degrees in engineering or science who are interested in an overview of HEL systems at some technical depth. The course emphasizes concepts, terminology, current technology capabilities, and systems concepts. Application of these concepts to current systems will include the historical Airborne Laser Laboratory, Airborne Laser, Tactical High Energy Laser, Advanced Tactical Laser, and Space Based Laser programs. The effectiveness of high energy laser weapons on the battlefield will be simulated using engagement and mission level models. There has been such a positive response from this course that the Directed Energy Professional Society (DEPS) is sponsoring a directed energy textbook based on this course. The authors include Dr. Robert Hengehold, Dr. Glen Perram, and Dr. Salvatore Cusumano from AFIT's Engineering Physics Department.

For those only interested in Beam Control or the Atmospheric Effects, the CDE offers a half-day course on each. The Directed Energy Professional Society has invited CDE to offer these short courses on Beam Control and HELEEOS 3.0 that covers atmospheric effects, at the DEPS Directed Energy Symposium in Monterey, California. The HELEEOS 3.0 includes a student hands-on demonstration. This provides potential users an excellent opportunity for a first-hand look at its capabilities.



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Designated by the Air Force Secretary and Chief

On June 19, 2008, the Secretary and Chief of Staff of the Air Force designated the Air Force Institute of Technology and the Center for Cyberspace Research (CCR) as the Air Force's Cyberspace Technical Center of Excellence (CyTCoE). The CyTCoE charter is to be a unifying and synergistic body for promoting cyberspace education, training, research, and technology development.

The CyTCoE will facilitate development of Air Force education and training in support of cyber operations as well as identify and provide subject matter experts that understand doctrine, techniques, and technology to ensure dominance and superiority in cyberspace. This designation enhances CCR's ability to be a clearinghouse for "who does what" and "who needs what" in cyber. The center will develop and strengthen relationships with, and maintain awareness

about the activities of various cyber-related research, education, and training communities within the Air Force, its service partners in the Department of Defense, and more. As the CyTCoE, the CCR will be a bridge between the operational AF cyber forces and various cyber research, education, and training communities across the Air Force, the DoD, and national organizations. Oversight and direction for the center is provided by a Board of Advisors, comprised of Air Force and DoD senior leaders.

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**AFIT Center for Cyberspace
Research Faculty Research
on Insider Threat
Recognized in Top 10 for
Innovative Research**

In April 2008, Network World published "25 Radical Network Research Projects You Should Know About," which highlighted articles from AFIT CCR faculty members Dr. Robert Mills and Dr. Gilbert Peterson. The articles were "Using PLSI-U to detect insider threat by data mining email," published in the International Journal Security and Networks, Vol 3, No 2, 2008, and "Using Author Topic to detect insider threats from email traffic," published in Digital Investigation 4, 2007. Network World affirmed that while "universities don't tend to shout as loudly about their latest tech innovations as do Google, Cisco and other big vendors, their results are no less impressive in what they could mean for faster, more secure and more useful networking." In the article, AFIT CCR's research is listed as the seventh 'need to know' research effort.

The research provides relevance to customers across Air Force, DoD, and the science and technology community. "The technology could help any organization sniff out insider threats by analyzing e-mail activity or find individuals among potentially tens of thousands of employees with latent interests in sensitive topics," according to the article. AFIT Center for Cyberspace Research continues to conduct cutting-edge research in both offensive and defensive cyber operations.

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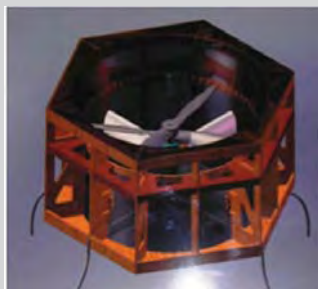
**"Cyber Warriors"
Win Digital Forensics
Challenge**

A team of four Computer Science and Cyber Operations graduate students from the Center for Cyberspace Research combined their cyber skills and interests in digital forensics to field a team in the annual DoD Cyber Crime Center (DC3) Challenge for 2007.

Using innovative techniques, the team cracked passwords, repaired damaged media, and more to accrue points in the challenge. In the end, AFIT's team, "Cyber Warriors" consisting of Maj. Andy Hansen, Al-Nath Tuting, Capt. Dorsey Wilkin, and 1st Lt. Mike Kolbe, took the Grand Champion trophy. AFIT's students represented the Air Force and CCR in a superb manner by placing first among the 126 teams that represented a broad range of students, faculty, and professional research. Challenges such as these demonstrate the value of graduate education and research and highlight the talents the Air Force is developing in support of the AFCYBER mission.

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Micro Air Vehicles for Indoor Combat Operations



The Advanced Navigation Technology Center is seeking to design, build, and test a ducted-fan Micro Air Vehicle suitable for indoor operation in populated environments.

Precision navigation is the cornerstone to the modern concepts of precision combat. The introduction of the Global Positioning System (GPS) has enabled a precision combat revolution. New tactics utilized by a combat force highly focused on sub-meter level accuracy produce maximum effects with minimum weapons. The Air Force's reliance on precision combat tactics, combined with a lack of alternative navigation technologies, has led to a dependence on GPS. Since GPS is unavailable indoors, this effort 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 the reliance on GPS, it introduces the overwhelming advantages of precision combat into mission areas which were previously impossible.

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Sensor Fusion for Inexpensive, Accurate Geolocation



The information collected by inertial and imaging sensors is complementary in nature. Unfortunately, the devices are typically designed for stand-alone operation and are not readily integrated. Furthermore, the dynamic nature of image and inertial sensor fusion on a moving platform demands a high level of fusion between sensors in order to maximize the performance of the integrated system. Currently, the National Geospatial Agency

is supporting the Advanced Navigation Technology Center in an effort to design, build, and test a precision geolocation system which accurately fuses GPS, inertial, and imaging sensors to improve target location accuracy. The system, designed to operate within a small unmanned aerial vehicle, records the collected data from all sources in a time-tagged metadata format, which is available for download immediately after the flight. The ultimate goal of this research is to develop a hand-launchable UAV with outstanding geolocation accuracy.

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Route Surveillance



Leveraging the previous research of fleeting targets, the Center for Systems Engineering and the Advanced Navigation Technology Center

(ANT) have joined forces in an attempt to fulfill the urgent needs of the Warfighter. The goal of this interdepartmental team is to demonstrate technologies enabling autonomous reconnaissance in support of convoy operations (routes) using multiple Micro Air Vehicle (MAV) platforms which will scale to other missions. A team of Systems Engineering and Aeronautical Engineering students are working to create a modular system

and software architecture for a semi-autonomous small air vehicle to accommodate a wide variety of route surveillance missions. Specific algorithms are being developed for the demonstration platform in the areas of sensor aimpoint control, collision avoidance systems, multiple MAV performance subject to transient conditions, and autonomous communication relay positioning. Students are utilizing specialized hardware in the ANT

laboratory to build flying prototypes of their concepts. Additionally, two Systems Engineering students have begun to model the interdependencies of factors that influence human operator trust in automation to better evaluate competing designs.

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Triage Tool for Response to Chemical-Biological Attacks

The Air Force Institute of Technology researchers have developed a prototype, The Situational Awareness/Triage Tool for use in a Chemical, Biological, Radiological, Nuclear, Explosive (CBRNE) environment. The system is a first-responder portable computer used to collect vital patient information such as medical/exposure history, patient identification, treatment, and environmental conditions. The system will ensure continuity of medical history, from incident scene to permanent medical treatment facility and provide on-scene commanders with near real-time situational awareness information. This will enhance the effective and efficient use of limited resources in a CBRNE environment, where there will likely be a significant number of patients requiring a range of medical attention even in the event low numbers of casualties are produced. The item provides several features and enhancements beyond the capabilities of current digitally formatted, medical triage tools.

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Mastering the Deployment and Distribution Problem

How can the Air Force locate supply points and vehicle depots and then develop good vehicle routes and schedules to ensure that the vehicles leave their depots, pick-up supplies, and deliver them to the warfighter in a timely manner? This is the theater distribution problem. When looked at more closely, it is composed of a number of difficult problems to solve in their own right: packing the pallet or container, loading the airlift aircraft, routing and scheduling the aircraft, refueling the aerial fleet, scheduling the crews, distributing all the assets in the theater, and choosing what mode to use (air, sea, truck, rail) throughout the supply network. This deployment and distribution problem is a huge, complex mathematical problem with many modeling challenges. AFIT's Department of Operational Sciences has developed a method to accomplish all of these tasks concurrently and minimize the cost of delivering supplies on time to meet the warfighter's needs. Testing on random generated problems showed the heuristic found the optimal solution 88% of the time. On two real world like scenarios, the heuristic solution reduced costs by over 100%.

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Preparing the Air Force Logistics Readiness Officer with the Right Analytic Toolkit

As the Air Force begins to implement the Expeditionary Combat Support System (ECSS), it is imperative that Air Force logisticians competently analyze logistics data. AFIT's Department of Operational Sciences has completed an extensive field study that determines which data analysis skills are most useful for Logistics Readiness Officers (LROs), as reported by active-duty LROs in grades O1-O5 and their supervisors. This research was aimed at identifying potential gaps between perceived usefulness and competence levels. Over 500 LROs and supervisors provided input through a designed survey instrument approach. A comprehensive literature review covering both the defense and civilian sectors confirmed and validated the research approach. Staff and operational officers,

responsible for all aspects of transportation and supply, including deployed location decision-makers, were included. Analysis of survey responses found that forecasting, graphical statistics, and descriptive statistics are the data analysis techniques valued most by both LROs and their supervisors. Responses were compared across statistical 'within groups' of LROs as well and found to be consistently similar. The newly-approved Department of Operational Sciences, Master of Science in Logistics and Supply Chain Management curriculum reflects the results of this educational research. This work was conducted under the auspices of the Air Staff A4.

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Hyperspectral Imaging for Plume and Transient Event Detection

The Center for Measurement and Signatures Intelligence Studies and Research and the Air Force Institute of Technology Remote Sensing group are developing space based methods for the classification of munitions type from fireball emissions, particularly the classification of Improvised Explosive Device (IED) events. These challenges are being addressed by: (1) developing unique hyperspectral imagers, (2) deploying a broad range of remote sensing equipment to collect ground truth signatures, and (3) developing simple, phenomenological models for low dimensional feature extraction and event classification.

A simple model for fireball emissions has been developed which accurately describes the observed spectra in terms of the fireball size, temperature, gaseous byproduct concentrations, and grey particulate absorption coefficient. The model affords high-fidelity dimensionality reduction and provides physical features which can be used to distinguish the uncased explosives. Battlespace awareness is increasingly dependent on breakthroughs in remote sensing, particularly for countering chemical and biological agent weapons and defeating IEDs. The stand-off detection of chemical, biological, and enhanced high explosive materials with wide area persistent surveillance may



be enabled by novel hyperspectral imaging technologies. These problems are particularly challenging when the sources are rapidly evolving, as is the case with most battlespace plumes and combustion events. The AFIT Remote Sensing group possesses the technical expertise as well as a suite of instruments that can be taken to the field to gather data and seek solutions to this challenging problem.

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Air Force Institute of Technology Support to the National Technical Nuclear Forensics Center

Imagine the unimaginable. A terrorist group detonates a nuclear weapon in a US city, but nobody lays claim to it. How does the US respond unless we know who made the weapon and how it was done? This is one scenario that is the focus of nuclear forensics research at AFIT in collaboration with the National Technical Nuclear Forensics Center at the Department of Homeland Security. Nuclear forensics is the fastest growing research group in AFIT's Graduate Nuclear Engineering program. AFIT has also partnered with Los Alamos National Laboratory, Oak Ridge National Laboratory, and the University of Florida for portions of the research, making this an interagency, multi-university research project.

Related research topics include using gamma spectroscopy; analysis of fallout patterns based upon location and weather; reducing detection time and sensitivity; exploring the

thermal effects on paints, plastics and other materials; and analyzing the local source region Electro Magnetic Pulse effects on ferromagnetics and plastics. The fundamental research effort includes use of atomic force microscopy, electron paramagnetic resonance measurements, and photoluminescence spectroscopy to determine the response of materials to the electromagnetic or thermal pulse. These are then related to weapon detonation parameters using physics based models to validate the methods and results.

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Low Observables, Radar and Electromagnetics Series Air Force Institute of Technology (AFIT) Research Aims to Boost Mission Capable Rates

AFIT faculty and students recently initiated a research thrust to improve current low observable (LO) aircraft maintenance tools and techniques. Unlike conventional aircraft, LO air vehicles incorporate sophisticated signature reduction systems to enhance survivability. Unfortunately these systems typically involve structures and materials particularly vulnerable to the harsh operational environment. Accurate signature health monitoring is paramount to maintaining weapon system effectiveness. AFIT's past research focused on developing a flight-line tool to quickly assess the material coatings on an LO aircraft. The current thrust has shifted to a mobile imaging radar system capable of quickly taking a "snap shot" of the entire aircraft to localize and assess trouble spots before flight.

Of particular interest to the Air Force Research Laboratory sponsor is the error propagation through the Circular Near-Field to Far-field Transformation algorithm used to take the close-in flight-line measurement to a far-field image representative of what an integrated air defense system would "see." The uncertainty analysis developed by AFIT researchers will provide a quantitative estimate of whether the hot spot seen with the flight-line radar should ground the aircraft or allow it to safely complete its mission.

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New "Safe and Arm" device based on Micro- Electro-Mechanical Systems (MEMS) and Nanotechnology

The AFIT microelectronics, micro-electro-mechanical systems and nanotechnology program has been actively researching critical Air Force and DoD initiatives including carbon nanotubes (CNTs), optical and RF metamaterials, biosensors and microrobots. The AFIT research group is currently teaming with five AFRL directorates, three in-house efforts, Sandia National Laboratory, and one local company to investigate current and future technologies ranging from weapon system safety to anti-tamper protection. One critical research initiative that is receiving significant emphasis involves improved design, development and testing of safe-and-arm devices used in current weapon system fuzing mechanisms. The safe-and-arm device is the primary component for enabling or disabling weapon detonation. Initial results include several robust design variations to accommodate a wide range of USAF and DoD weaponry. Additionally, the current safe-and-arm design, under patent review, will be live-fire tested by AFRL's Munitions Directorate in the near future. This critical research directly impacts current warfighters, in the continued war on terror, and provides for safe weapons handling by USAF maintainers. A unique capability of this MEMS-based safe-and-arm design is the ability to disarm and re-safe the weapon system. This vital capability is needed to prevent inadvertent weapon detonation thereby minimizing collateral damage and preventing the unnecessary loss of life.

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Enhancing UAV Communications Efficiency

As the unmanned air vehicle (UAV) becomes more ubiquitous in the modern battle space, the need to compact sensor and communication systems for ever-shrinking platforms becomes paramount. Unfortunately physics conspires against researchers as they try to transmit and receive radio frequency electromagnetic radiation through smaller and smaller antennas. Below aperture sizes on the order of a wavelength, much of the power is reflected by the antenna rather than transmitted. This problem severely limits the ability of small UAVs to efficiently support low frequency communication waveforms. Air Force Institute of Technology researchers, in conjunction with the Air Force Research Laboratory, are pursuing a non-traditional antenna design approach to "cheat" those pesky physical laws. By exploiting the dimension of time, it is possible to create a series of time-limited waveforms whose high frequency content permits easy transmission through small antenna apertures applicable to the UAV platform. These waveforms are fired in sequence Gatling gun style to combine at the target and produce the desired low frequency waveform. This novel wavelet-based low frequency synthesis concept enables efficient transmission of low frequency communication signals from small UAV antennas. AFIT faculty and students plan to demonstrate the concept in the laboratory using an arbitrary waveform generator and a small array of microwave X-band horns.

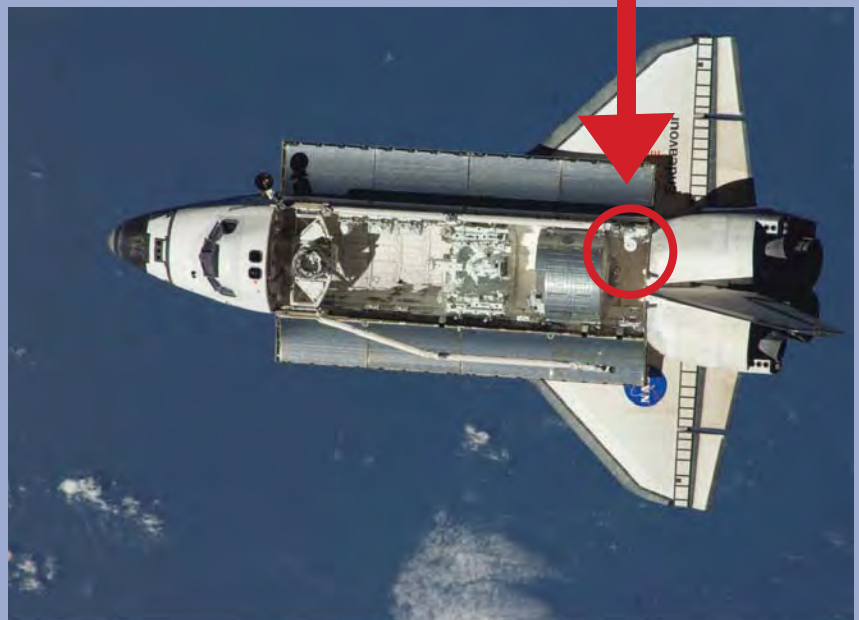
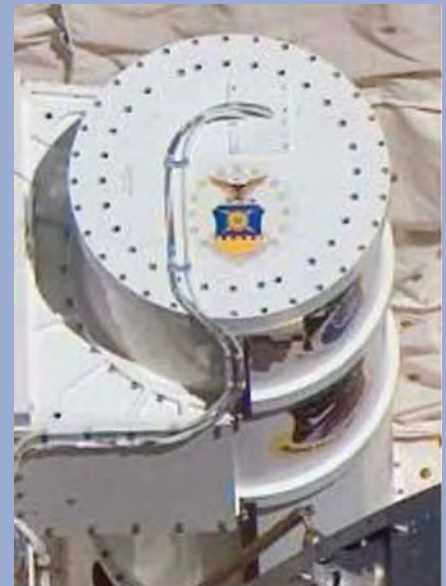
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Air Force Institute of Technology Rigidizable Inflatable Get-Away-Special Experiment (RIGEX) Flown on Space Shuttle

On March 11th 2008, space shuttle Endeavor carried aloft an experiment designed, built and tested by students at the Air Force Institute of Technology. The RIGEX project, which stands for Rigidizable Inflatable Get-Away-Special Experiment, was designed to test and collect data on rigidizable and inflatable space structures. Current satellites and their accompanying antennas are often limited in size due to limited launch vehicle dimensions. Success of this technology helps alleviate some of the size limitations for future space missions.

Integrated and flown under the direction of the Department of Defense Space Test Program, AFIT students designed, built, and space qualified the experiment. The experiment was the collective thesis effort of AFIT students as part of their degree requirements towards a Master of Science degree in engineering. The project involved multiple students from the Aeronautical, Astronautical, Electrical and Systems Engineering programs. They worked closely with the DoD's Space Test Program at the Johnson Space Center to make sure their design satisfied all the NASA requirements for manned spaceflight. RIGEX represents the first-ever designed/built/tested space flight experiment for AFIT. On-orbit, the experiment successfully deployed three rigidizable inflatable tubes while simultaneously collecting temperature, pressure, acceleration and video data for post flight analysis. At the end of the 16 day shuttle mission, the experiment was returned to AFIT for final post flight analysis. Final results and conclusions from the experiment will be presented at an upcoming AIAA Structural Dynamics and Materials conference.

Dr. Cobb, an Assistant Professor of Aerospace Engineering in the Department of Aeronautics and Astronautics, was the key faculty member for the space shuttle experiment. His research focuses on dynamics and control of large structures for space-based remote sensing, and optimization and control for aerospace applications. Dr. Cobb is an associate fellow of AIAA.



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2008 Commandant Award and Geospatial Intelligence Award

Captain Robert Johnson, a March 2008 Graduate from AFIT's Operations Research Program and the Commandant's Award winner was selected by the United States Geospatial Intelligence Foundation as the 2008 recipient of the Geospatial Intelligence Award for Academic Research for his master's thesis "Improved Feature Extraction, Feature Selection, and Identification Techniques that Create a Fast Unsupervised Hyperspectral Target Detection Algorithm."

American Society of Mechanical Engineers Award



Amber McClung, a Dayton Area Graduate Studies Institute PhD student in the Department of Aeronautics and Astronautics, authored a paper that has been selected as the winner in the 2008 American Society of Mechanical Engineers Pressure Vessel and Piping Division International Student Paper Competition, PhD category. Amber received an award certificate and a \$2,000 prize at the ASME PVP-2008 international conference in July, where

she presented her paper entitled "Strain Rate Dependence and Short-Term Relaxation Behavior of a Thermoset Polymer at Elevated Temperature: Experiment and Modeling."

The paper, described by ASME reviewers as "excellent" and "well-written," was co-authored by McClung's advisor, Dr. Marina Ruggles-Wrenn.

Cyber Alumni Profile



Lt Col (s) Timothy P. Franz, March 2007 alumni, was one of the first graduates of AFIT's newest Master's program, Cyberspace Operations. His research developed an Information Operation career field and presented a "way ahead" for the Air Force. His thesis was the first to offer such comprehensive strategies for the development of a professional force in this arena and earned him top honors upon

graduation. Post graduation, he was assigned to Barksdale AFB, Louisiana, to help stand up the new Air Force Cyber Command.

As Chief of Force Development, he developed strategies and lead efforts to create the Air Force corp of cyberwarfare professionals. Recently, Major Franz was selected as the Commander of the 57th Information Aggressor Squadron at Nellis AFB.

Graduate Nuclear Engineering Program Offers Unique Student Experiences



The Air Force Institute of Technology graduate programs are special in content, focused on US Air Force science applications and nuclear weapons. It prepares students to fill roles as joint staff planners, program managers, analysts, and researchers in Air Force and Army commands. Students often fill these roles in the Defense Threat Reduction Agency (DTRA), Department of Energy, Defense Homeland Security (DHS), and National Nuclear Security Agency. A unique aspect of AFIT's nuclear engineering program is a week long, hands-on educational experience at Los Alamos National Laboratories, Sandia National Laboratories, Defense Nuclear Weapons School, Kirtland Underground Munitions Storage Complex, and DHS. The field trip is sponsored by the DTRA/CS. This exercise is unique to these graduate programs and an essential educational component. The annual trip is scheduled during the 18 month graduate program after students have completed rigorous coursework covering the physics and effects of nuclear weapons, detection of special nuclear materials, radioactive materials production methods, and experimental techniques used in basic and applied nuclear weapon research. PhD experts are present at each location, allowing students to interact.

Secretary of the Air Force Leadership Award

Capt Peter Mastro, currently a graduate student in the Department of Aeronautics and Astronautics, was awarded the 2008 Secretary of the Air Force Leadership Award for being selected as the #1 student from all 2007 Squadron Officer School classes, which included over 3,000 Air Force officers, international officers, and Department of Defense civilian students. Capt. Mastro distinguished himself among his peers due to his exceptional initiative, enthusiasm and leadership qualities. Secretary of the Air Force Michael W. Wynne presented the award, along with three other leadership awards, in May 2008 at Maxwell AFB.

The Frank and Lillian Gilbreth Award



Marlin U Thomas, Dean of the Graduate School of Engineering and Management, distinguished himself through the contributions to the welfare of humankind in the field of industrial engineering. At the Institute of Industrial Engineers Annual Conference and Expo, Dean Thomas was presented the Gilbreth Award, IIE's highest and most esteemed honor.

2008 Captain P.V.H. Weems Award

Dr. Peter S. Maybeck, is the recipient of the Institute of Navigation Captain P.V.H. Weems Award for his lifelong accomplishments in navigation education and research.

As a professor of electrical engineering at the Air Force Institute of Technology, Dr. Maybeck has directly impacted every AFIT guidance, navigation, and control graduate student since 1973 (over 500 Air Force officers). Dr. Maybeck has been directly responsible for AFIT's graduate sequence in estimation and stochastic control and for individual advanced digital filtering and controls courses, research, advising of masters and doctoral research, and consulting for Air Force and DoD organizations. He is the author of more than one hundred technical publications on applied optimal filtering as well as the book, *Stochastic Models, Estimation and Control*.

2008 Air Force Outstanding Scientist and Engineering Educator Award



Dr. Richard A. Raines, Professor of Electrical Engineering and Director, Center for Cyber Research (CCR), was awarded the Air Force Outstanding Scientist and Engineering Educator Award; this award recognizes outstanding contributions in education, as well as technological leadership abilities. He organized and developed technically-focused,

graduate-level curricula in cyber operations and research, including an "Offensive Cyber Operations" course. This course presents cutting-edge topics addressing network attack, network security, ethics, doctrine, policy, law, and network operations. Dr. Raines also provided essential guidance in the development of AFCYBER(P)'s mission area and the cyber career field.

2008 Air Force Outstanding Scientist Award, Junior Civilian



Dr. Gilbert Peterson, Assistant Professor, Department of Electrical and Computer Engineering, was awarded the Air Force Outstanding Scientist Award, Junior Civilian; this award recognizes outstanding contributions in scientific studies and research, as well as technological leadership abilities. Dr. Peterson led the development of optimal power management usage strategies

for autonomous vehicles resulting in increased loiter times for vehicles such as unmanned aerial vehicles and ground-based robots. His Insider Threat research was ranked 7th internationally, in the "Top 25 Radical Network Research Projects You Should Know About" in *Network World*, bringing positive publicity and over \$1M of external funding to AFIT. He also led AFIT's Cyber Forensics Team in the annual DoD Cyber Crime Center Challenge where they won 1st Place Grand Champion honors.

Directed Energy Professional Society Fellow

Dr. Glen P. Perram, Professor of Physics, was selected as a fellow by the Directed Energy Professional Society (DEPS) at the 10th Annual DEPS Symposium. Dr. Perram was recognized for his research expertise, technical contributions, and impact as an educator within the DEPS community. A leader in his field, Dr. Perram is recognized as a subject matter expert in the disciplines of laser spectroscopy, and chemical kinetics as it relates to chemical laser devices. Dr. Perram's scholarly contributions include 41 journal articles and 158 conference papers. During 2008 he mentored 4 Masters students and 11 PhD students, while supporting an annual research portfolio valued at \$1.4M. Dr. Perram is a charter member of DEPS and the former director of the AFIT Center for Directed Energy.

2008 Dr. Fritz J. Russ Bioengineering Award



Dr. Gary B. Lamont, Professor of Electrical Engineering, was awarded the IEEE Dr. Fritz J. Russ Bioengineering Award; this award recognizes engineering achievement that has had a significant impact on society and has contributed to the advancement of the human condition through widespread use.

New FY08 Awards to Academic Departments & Research Centers by Type

* All center funds are also included in departmental funding.

Department	Research		Education		Total	
	#	Dollars	#	Dollars	#	Dollars
Mathematics & Statistics (ENC)	4	92,277	-	-	4	92,277
Electrical & Computer Eng (ENG)	61	2,924,267	6	1,241,272	67	4,165,539
Engineering Physics (ENP)	38	2,837,068	4	890,078	42	3,727,146
Research & Sponsored Programs (ENR)	1	10,000	-	-	1	10,000
Operational Sciences (ENS)	11	999,763	-	-	11	999,763
Systems & Eng Management (ENV)	11	604,777	1	60,000	12	664,777
Aeronautical & Astronautical Eng (ENY)	36	958,109	-	-	36	958,109
TOTAL	162	8,426,261	11	2,191,350	173	10,617,611

Center*						
Advanced Navigation Technology Center (ANT)	18	828,391	-	-	18	828,391
Center for Directed Energy (CDE)	19	1,755,674	1	51,168	20	1,806,842
Center for Cyberspace Research (CCR)	15	764,718	6	1,241,272	21	2,005,990
Center for MASINT Studies and Research (CMSR)	7	493,044	1	756,000	8	1,249,044
Center for Operational Analysis (COA)	9	1,046,563	-	-	9	1,046,563
Center for Systems Engineering (CSE)	7	496,852	1	60,000	8	556,852
TOTAL	74	5,385,242	9	2,108,440	83	7,493,682

New Award History FY00-FY08

Education

Research

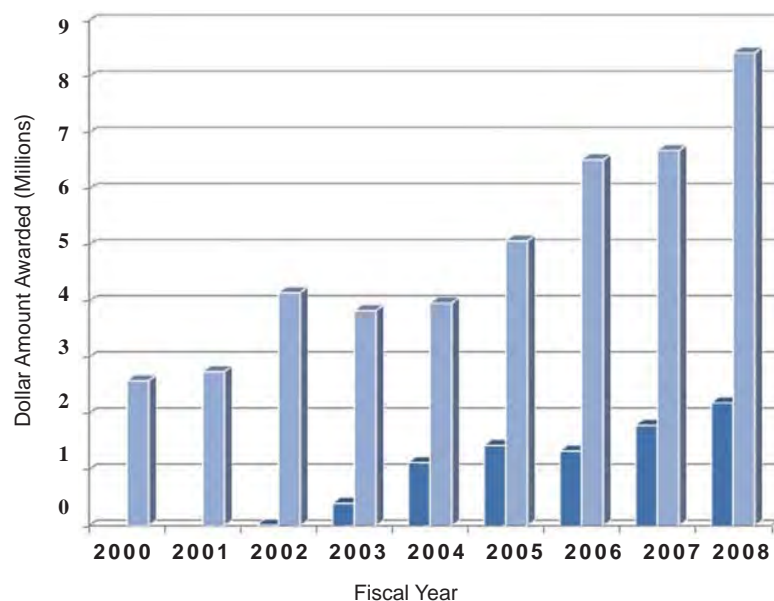
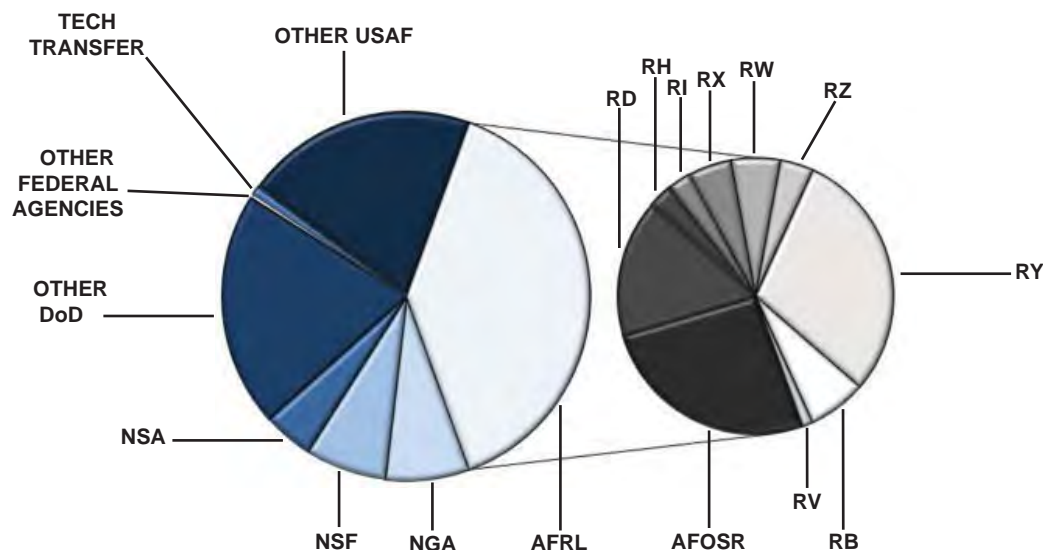


Figure 2.3: Sponsors of FY08 Funded Projects

* Pie chart on the right shows breakdown by AFRL Directorate.



New FY08 Awards to Academic Departments & Research Centers by Sponsor

* All center funds are also included in departmental funding.

	AFRL	Other USAF	Other DoD	NGA	NSF	NSA	Other Federal	Non-Federal	Total
Dept.	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>
ENC	92,277	-	-	-	-	-	-	-	92,277
ENG	2,036,616	713,738	409,349	30,000	528,424	447,412	-	-	4,165,539
ENP	984,573	548,736	1,134,320	756,000	230,000	-	29,209	44,308	3,727,146
ENR	10,000	-	-	-	-	-	-	-	10,000
ENS	66,500	316,293	596,970	-	-	20,000	-	-	999,763
ENV	145,000	481,692	30,385	-	-	-	7,700	-	664,777
ENY	794,615	109,634	15,000	-	-	-	-	38,860	958,109
TOTAL	4,129,851	2,170,093	2,186,024	786,000	758,424	467,412	36,909	83,168	10,617,611
Center*	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>
ANT	752,491	45,900	-	30,000	-	-	-	-	828,391
CCR	637,075	94,530	298,549	-	528,424	447,412	-	-	2,005,990
CDE	806,787	9,000	761,055	-	230,000	-	-	-	1,806,842
CMSR	-	434,736	14,000	756,000	-	-	-	44,308	1,249,044
COA	59,500	279,293	707,770	-	-	-	-	-	1,046,563
CSE	55,000	159,552	322,140	-	-	-	-	20,160	556,852
TOTAL	2,310,853	1,023,011	2,103,514	786,000	758,424	447,412	-	64,468	7,493,682

Air Force Institute of Technology Sponsor Funding – Large Awards* FY08

* Large Awards are those that earn \$150,000 or more for a single proposal in the given fiscal year.

Graduate School of Engineering and Management

AFIT Analysis Support to the Joint Improvised Explosive Device Defeat Organization

\$1,130,210 – Joint Improvised Explosive Device Defeat Organization (JIEDDO) (Multiple departments, centers, and investigators)

Department of Electrical and Computer Engineering

Advanced Navigation Technology Center (ANT)

ANT Center and Laboratory Support

\$185,000 – Air Force Research Laboratory Sensors Directorate (AFRL/RYS)
Principal Investigator: Dr. John F. Raquet

Center for Cyberspace Research (CCR)

Development of a Federal Cyber Force at the Air Force Institute of Technology

\$528,424 – National Science Foundation (NSF)
Principal Investigator: Dr. Richard A. Raines

IASP Tuition and Resource Support for the AFIT Center for Cyberspace Research

\$312,848 – National Security Agency (NSA)
Principal Investigator: Dr. Richard A. Raines

AFIT Transformation Chair

\$168,000 – Department of Defense/Office of the Secretary Defense (DoD/OSD)
Principal Investigator: Dr. Richard A. Raines

Technical Support: Autonomic Infusion

\$152,676 – AFRL Sensors Directorate (AFRL/RYS)
Principal Investigator: Dr. Gilbert L. Peterson

Anti-Tamper Software Protection Initiative Education, Outreach and Research

\$200,000 – AFRL Sensors Directorate (AFRL/RYS)
Principal Investigator: Dr. Richard A. Raines

Department of Engineering Physics

Center for Directed Energy (CDE)

HELJTO Model & Simulation

\$400,000 – AFRL Directed Energy Directorate (AFRL/RD)
Principal Investigator: Dr. Salvatore J. Cusumano

High Energy Laser-Laser Communications Performance Assessments from Remotely-Sensed Measurements of Atmospheric Beam Scatter

\$230,000 – National Science Foundation (NSF)
Principal Investigator: Dr. Salvatore J. Cusumano

Technical and Administrative Support for the AFOSR Center of Excellence in High Power Gas Phase and Electric Lasers

\$220,000 – AFRL Directed Energy Directorate (AFRL/RD)
Principal Investigator: Dr. Glen P. Perram

High Power Diode Pumped Alkali Vapor Lasers and Analog Systems

\$176,000 – AFRL Directed Energy Directorate (AFRL/RD)
Principal Investigator: Dr. Glen P. Perram

Center for MASINT Studies and Research (CMSR)

Advanced Geospatial Intelligence Education

\$756,000 – National Geospatial-Intelligence Agency (NGA)
Principal Investigator: Dr. Ronald F. Tuttle

AFIT Faculty Member Receives Prestigious Young Investigator Research Award



The Air Force Office of Scientific Research awarded approximately \$12.1 million in grants to 39 scientists and engineers nationwide who submitted winning research proposals through the Air Force's Young Investigator Research Program. Congratulations to Maj Jason Schmidt, an assistant professor of electro-optics in the Department of Electrical and Computer Engineering for being the only military member to receive the award.

With this funding Maj Schmidt and his students will conduct basic research in adaptive optics, a technology that compensates for the dynamic blurring effects that atmospheric turbulence has on light.



<http://www.afit.edu/de>



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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. For more information please contact The Office of Research and Sponsored Programs: research@afit.edu

AFIT Directory

For specific information regarding faculty and their research areas, please visit: <http://www.afit.edu/directory/>

This Annual Report is published annually by the Air Force Institute of Technology (AFIT) Office of Research and Sponsored Programs (ENR) at Wright-Patterson Air Force Base, OH. It shares information about the activities of the Graduate School of Engineering and Management at AFIT with the AF, the DoD, and the wider public. All pictures are USAF or AFIT photos unless otherwise identified. The Department of Defense, other federal government, and non-government agencies supported the research reported herein, but have not reviewed or endorsed the contents of this brochure. AFITRP 65-3

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Official Publication of the Air Force Institute of Technology

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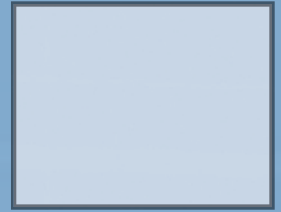
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