

AIR FORCE INSTITUTE OF TECHNOLOGY  
*Graduate School of Engineering and Management*

**20**

**ANNUAL REPORT**

**13**



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**Cover photo:** Artist rendering of the ALICE satellite orbiting Earth. To read more about ALICE, AFIT's first satellite in space, see "Carbon NanoTube Field Emission Arrays Go To Space" on page 6.

## RESEARCH *Centers*

The Air Force Institute of Technology is home to the centers listed below, which bring together experts from diverse disciplines to focus efforts on specific interdisciplinary challenges. By sharing expertise, facilities, and equipment, centers provide the synergy required to solve difficult problems.

Advanced Navigation Technology Center	<a href="http://www.afit.edu/en/ant/">http://www.afit.edu/en/ant/</a>	Dr. John Raquet
Center for Directed Energy	<a href="http://www.afit.edu/en/de/">http://www.afit.edu/en/de/</a>	Dr. Steven Fiorino
Center for Operational Analysis	<a href="http://www.afit.edu/en/coa/">http://www.afit.edu/en/coa/</a>	Dr. Darryl Ahner
Center for Space Research and Assurance	<a href="http://www.afit.edu/en/csra/">http://www.afit.edu/en/csra/</a>	Dr. Jonathan Black
Center for Technical Intelligence Studies & Research	<a href="http://www.afit.edu/en/ctisr/">http://www.afit.edu/en/ctisr/</a>	Dr. David Bunker
Air Force Center for Cyberspace Technical Excellence	<a href="http://www.afit.edu/en/ccr/">http://www.afit.edu/en/ccr/</a>	Dr. Robert Mills
Center for Cyberspace Research		
OSD Scientific Test and Analysis Techniques in Test and Evaluation Center of Excellence	<a href="http://www.afit.edu/en/stat_te_coe/">http://www.afit.edu/en/stat_te_coe/</a>	Dr. Darryl Ahner

# MESSAGE FROM THE *Dean*



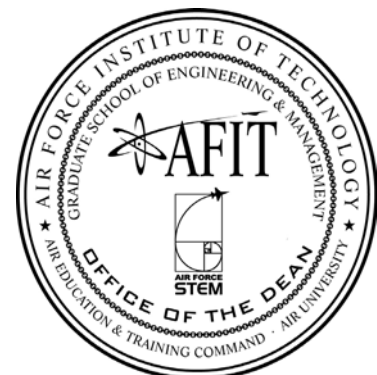
Seven years ago I chose to come to AFIT because of its outstanding faculty, strong multi-disciplinary collaborations, and the nearly limitless opportunities to contribute to the advancement of educational programs of the US Air Force. AFIT's unique research-based, defense-focused education is indispensable to the defense of our nation and extremely valuable to our research partners, who represent government agencies, academia, and industry. Despite the current financial challenges facing the Air Force, AFIT continues to work hard toward improving the efficiencies and effectiveness of a smaller-sized Air Force. As the new dean of AFIT's Graduate School of Engineering and Management, I am excited and enthused about the opportunities that lie ahead of us.

This year has been an exhilarating one for the Graduate School with faculty and students earning notable recognitions for their research and teaching. The 2013 Annual Report highlights these achievements as well as the unique research efforts of the Center for Space and Research Assurance (CSRA) and the OSD Scientific Test and Analysis Techniques in Test and Evaluation Center of Excellence (STAT T&E COE). On December 5th, 2013 CSRA's CubeSat micro-satellite, AFIT LEO iMESA CNT Experiment (ALICE), was successfully launched into Space. We are also, particularly, proud of CSRA's involvement with students completing research projects that directly align with the Department of Defense (DOD) and Air Force priority areas to solve real problems for the nation. Likewise, the STAT T&E COE continues to provide significant value to the test and evaluation planning efforts for approximately 25 Acquisition Category (ACAT) I programs across the DOD.

On behalf of the Graduate School, I would like to offer my gratitude to Dr. Heidi Ries, Dean for Research, for her leadership and dedication while serving as interim dean from January to September 2013. Dr. Todd Stewart, AFIT Director and Chancellor, honored Dr. Ries with the Air Force Exemplary Civilian Service Award for her distinctive accomplishments, outstanding initiative, and tireless dedication. Her broad knowledge of the School and her demonstrated ability to both manage and lead has steadily guided us through this tumultuous time of government furloughs and budget sequestrations.

As AFIT celebrates its 95th anniversary, we remain a strong and robust academic institution. Our graduates, students, faculty, and staff are very proud of our long distinguished history of educational and research accomplishments in support of the Air Force mission. As I begin my tenure as Dean, I will use the Air Force core values to set the foundation and tone of our activities: "Integrity first, Service before self, Excellence in all we do." I look forward to an exciting year ahead!

Respectfully,  
Adedeji B. Badiru, Ph.D., PE  
Dean, Graduate School of Engineering and Management  
Air Force Institute of Technology



# CENTER FOR *Space and Research Assurance*

The Center for Space Research and Assurance (CSRA) was established in November 2012. The creation of the CSRA provided an organization to look at future DOD Space needs and present a formal research-based graduate education program to meet those needs through hands-on training and practical experiences. In order to achieve the practical experiences for the students, the CSRA has multiple areas of research across multiple departments. Focus areas include propulsion, astrodynamics, space systems architectures, guidance and navigation, and communications. In addition, students in the Astronautical Engineering and Space Systems degree programs, as well as space-focused students in other degree programs take a specialized course sequence to design, build, and test a class of micro-satellites known as CubeSats.

The CSRA also provides active collaboration among DOD research organizations and other departments within AFIT to supply an interdisciplinary portfolio to address the needs of the space domain. Additionally, our collaborations with the Defense Advanced Research Projects Agency (DARPA), Air Force Research Laboratory (AFRL), United States Strategic Command (USSTRATCOM), Missile Defense Agency (MDA), and Space and Missile Systems Center (SMC) provide external support for the CSRA. In FY12, the CSRA received a total of approximately \$2.3M to support spaceflight programs (\$1.3M), research (\$800K), and educational programs (\$200K). In FY13, support totaled approximately \$1.2M for our various programs as well.

Over a five-year period, AFIT will graduate approximately 125 highly-educated military and civilian personnel capable of the technical work associated with space. Our graduates are assigned to the Air Force Material Command (AFMC) and other MAJCOMs such as Air Force Space Command (AFSPC), Air and Education Command (AETC), and Air Combat Command (ACC). The remaining graduates are assigned to other agencies such as the National Reconnaissance Office (NRO), Air Force Headquarters (HQ AF), and sister service organizations.



**CSRA Faculty and Staff**

## Mission

Execute cutting-edge space technology development, science, and space experiments in collaboration with government organizations to meet the challenges of tomorrow by developing the technical space cadre through world-class research and immersive hands-on graduate education

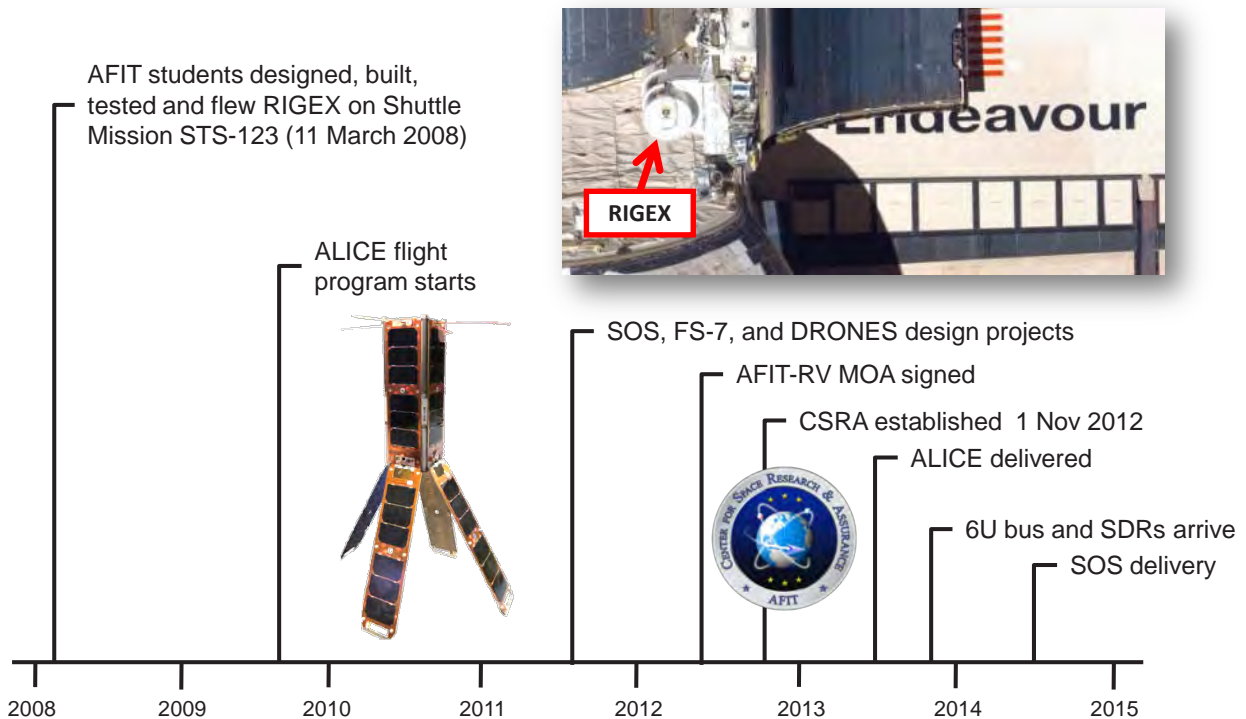
## Vision

Deliver highly-valued resilient, responsive, and reliable space capabilities

## Research Areas

- Payloads (includes ground processing)
- Space Platforms (Bus Technologies including cost modeling)
- Advanced Experiments (New Concepts of Operation)
- Space Situational Awareness and Assurance
- Space Access (launch)

For more information, visit <http://www.afit.edu/en/csra>.



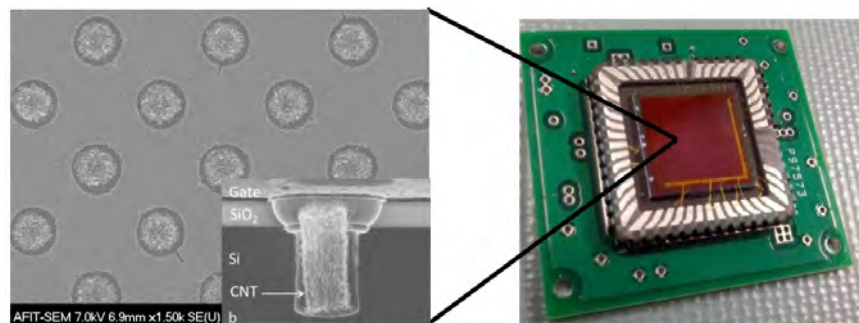
**CSRA Timeline**

## Carbon NanoTube Field Emission Arrays Go To Space

AFIT's ALICE satellite was successfully launched on an Atlas V rocket with the GEMSat/ELaNa II NASA mission in December 2013, culminating a five year development effort by AFIT faculty and students. ALICE carries an experimental payload that will test new carbon nanotube (CNT) technology to enable the extraction of free electrons through a very efficient process called Field Emission (FE).

Electronic FE is a gateway technology for many applications of interest to the DOD and commercial industry. Everything from spacecraft propulsion to flat-screen display technology stands to benefit from a low voltage, highly efficient electron source such as the CNT arrays being investigated at AFIT. In contrast to the more common thermionic electron sources where thermal energy is used to "boil off" electrons from the surface of the emitter (think of a light bulb filament), field emission uses large electric fields to extract electrons from the surface. This "cold cathode" approach is very efficient because most of the energy in the extraction field is used to generate emitted electrons without the wasted heat energy of the thermionic approach. CNTs are excellent candidate materials for the FE application due to the very "sharp" geometry of the nanotubes and their excellent current carrying capacity.

In partnership with the Georgia Tech Research Institute, AFIT has recently developed an integrated CNT FE array where the CNTs are grown in thousands of tiny wells on an insulating substrate (Figure 1). A conductive top layer provides the ability to create a large local electric field to extract electrons from the CNTs. The tiny distance between the gate and CNTs creates this large field strength with a relatively small applied voltage. Despite the promise of this design, there are still many difficulties limiting its applicability. The space environment in particular provides challenges in terms of contamination, charged particle exposure, and thermal cycling.

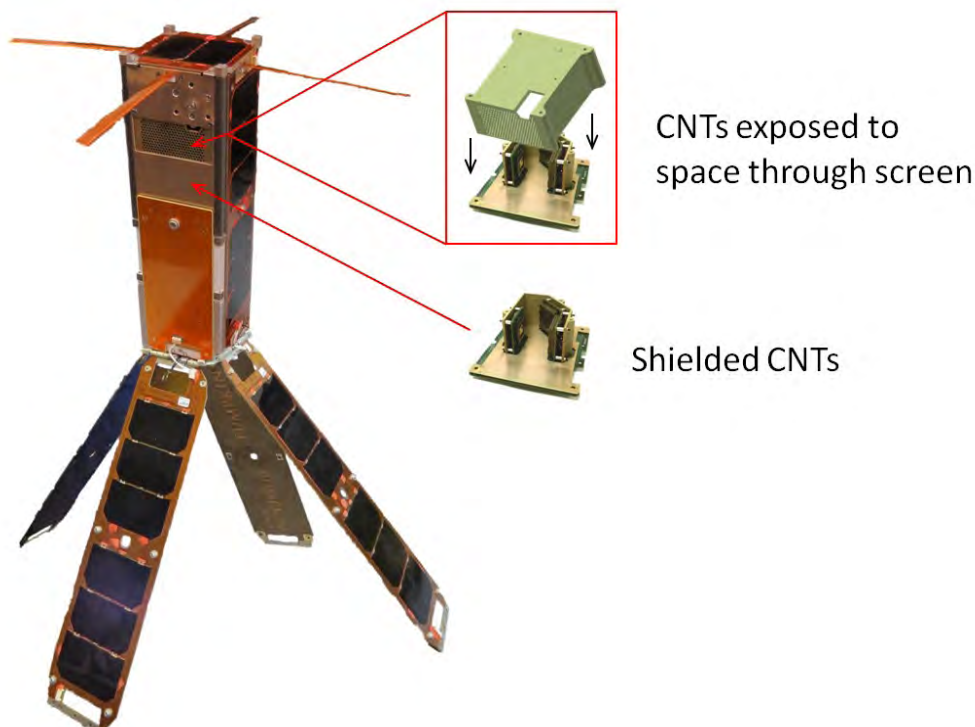


**Figure 1. Photo on the left shows CNT cluster co-aligned with gate. Photo on the right shows many CNTs arranged in a grid creates an FE array.**

To better understand how the new CNT FE array will perform under the challenges of the space environment, AFIT Professor of Electrical Engineering Dr. Peter Collins led a team of students to develop a payload concept called "ALICE". The basic idea is to fly two identical CNT arrays where one is exposed to the contaminants and charged particles of the space environment while the other is shielded (Figure 2). The performance of the

CNT arrays is measured by an integrated miniature electrostatic analyzer (iMESA) developed by the United States Air Force Academy. The on-orbit data will be compared with data taken on the ground in AFIT's CNT characterization laboratory to provide an assessment of the impact of long-term space environment exposure on the CNT arrays.

The first of AFIT's free flying satellites, ALICE is a 5"x5"x15" 3U CubeSat (a type of miniaturized satellite) designed to power and control the CNT characterization experiment, store the acquired data, and communicate it to the ground through an on-board radio. The ALICE payload will continually monitor the performance of the exposed and shielded CNT arrays over time, beaming the data down to a ground station at AFIT's Center for Space Research and Assurance. Data from the December 2013 launch will be collected directly at AFIT using the Center for Space Research and Assurance's satellite ground station over the expected 1 year lifetime of the ALICE CubeSat. The data collected includes CNT emission characteristics such as the electron density and energy spectra as a function of applied voltage, operating temperatures, and supply currents and voltages. In addition, the satellite state of health data will also be collected and analyzed to assist with any required trouble shooting operations.



**Figure 2. ALICE CubeSat showing two identical CNT arrays with one exposed to space and the other shielded from contamination and charged particles.**

*CONTACT*  
Dr. Peter Collins  
Peter.Collins@afit.edu • 937-255-3636 x7256

## Space Propulsion

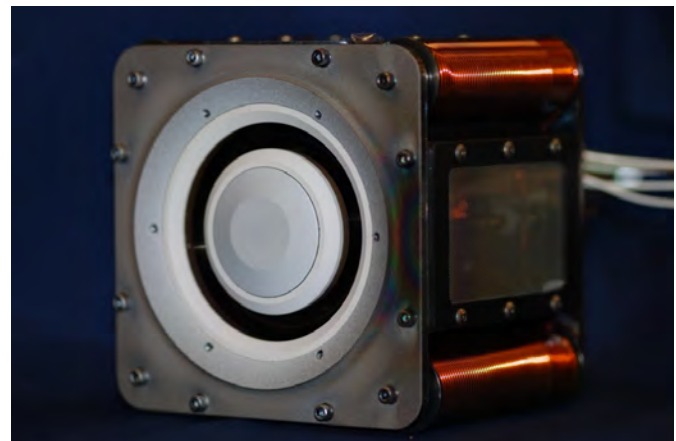
Space propulsion, with emphasis on electric propulsion systems, is an important area of research for AFIT's CSRA. Currently, AFIT has three space vacuum chambers which simulate the space environment. The largest vacuum chamber, which resides in the Space Propulsion Analysis and System Simulation (SPASS) Laboratory, is capable of testing electric propulsion systems such as a 1500W-class Hall thruster used for orbit maintenance and station keeping.



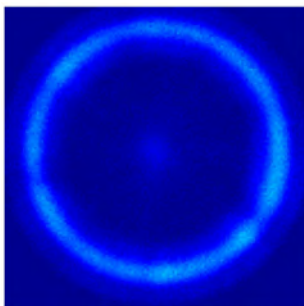
**1500 Watt Hall effect thruster operating with xenon propellant at the SPASS Laboratory.**

Students are currently investigating the plasma instabilities which have been observed in Hall thrusters. CSRA researchers are using advanced high-speed imagery and other measurement techniques to better understand the physics of these instabilities inside the thruster plume. This research will help to increase the performance and efficiencies of next generation thrusters.

In addition, researchers are conducting in-house testing of micro-electric propulsion systems for nano-satellites such as the 6-U CubeSat. The research for nano-satellites has led to new applications such as micro-Hall thrusters, micro-ion engines, and micro-pulsed plasma thrusters.



**Busek 600 Watt Hall effect thruster**



**Left: Color enhanced image of azimuthal plasma instability within the discharge of a 600 Watt Hall effect thruster. The bright regions are the direct visible emission of the plasma captured at one million frames per second with a 750  $\mu$ s exposure time.**



**Right: 20 Watt Micro-Hall effect thruster operating with xenon propellant.**

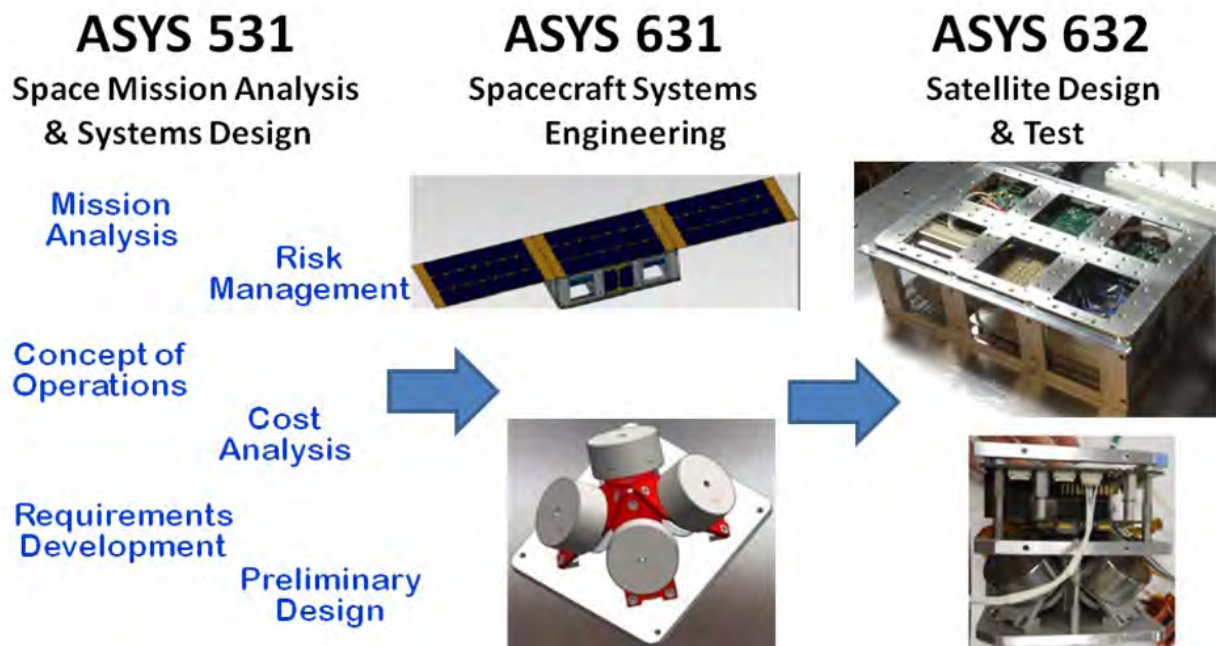
### *CONTACT*

Capt David Liu  
David.Liu@afit.edu • 937-255-3636 x4542

## Satellite Design, Build, and Test Course Sequence

AFIT's three-course Space Vehicle Design specialty sequence, coordinated through the CSRA, consists of the systems engineering focused Space Mission Analysis and Systems Design, satellite design in Spacecraft Systems Engineering, and the immersive hands-on prototype build and space qualify Satellite Design and Test. This unique three-course approach gives students experience in taking a space mission through all phases of mission concept design and analysis, sub-system design, to space hardware construction resulting in an engineering development unit (EDU). Design groups and projects are consistent throughout the three courses, allowing continuity from one class to the next and a great deal of depth to the final products.

While the courses typically require two to three times as much time and effort as a traditional non-lab/design course, they are extremely popular with students. Much of the sequence's popularity is due to the focus on sponsor-funded design projects. With the motivation that they are designing satellites for real Air Force missions, the 7-person student teams achieve advanced levels of design maturity. The final satellites (recently a focus on 6U CubeSats) approximate real Cubesats in form, fit, and function, and pass many aspects (Vibe, TVac, and Function) of a full space qualification test program. In total, students who complete AFIT's Space Vehicle Design sequence develop a practical and wide-ranging understanding of the design, development, and testing of satellite systems, and all of the space-focused gaining organizations request that their students take this sequence.



### CONTACT

Dr. Eric Swenson

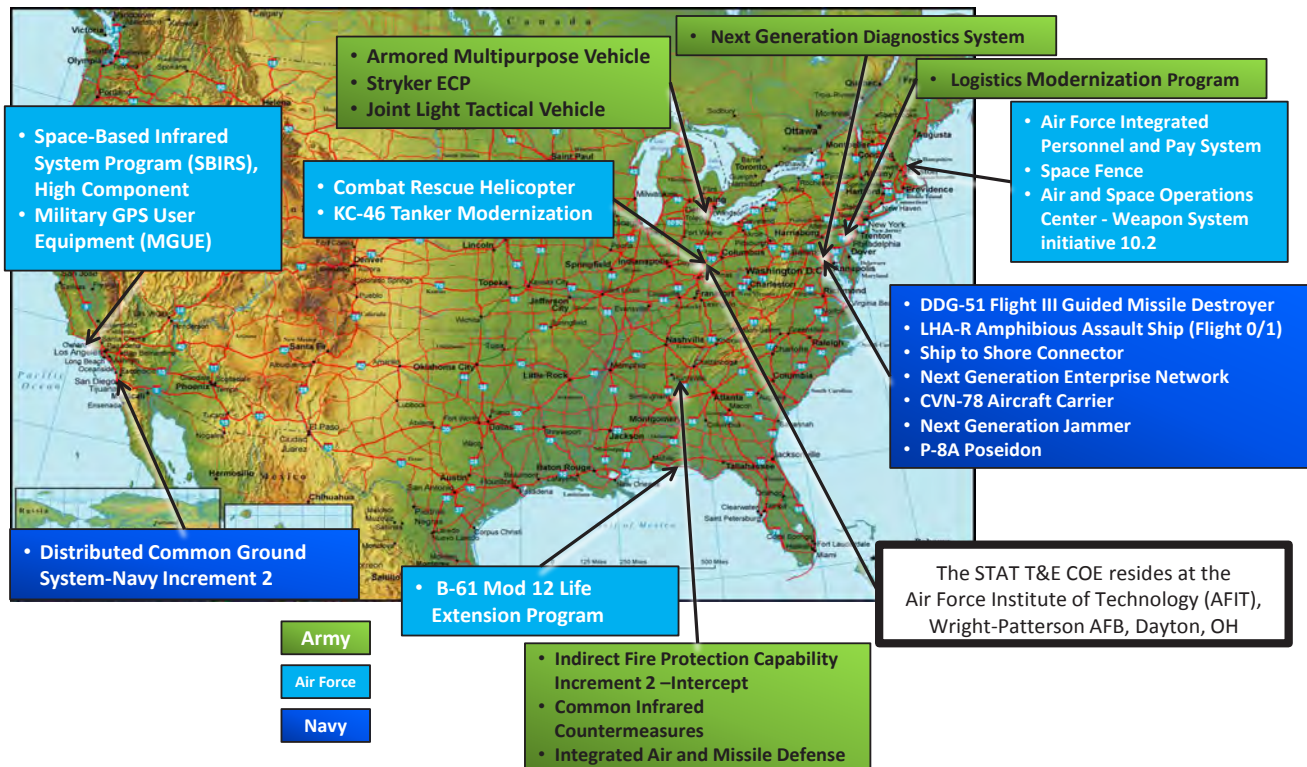
Eric.Swenson@afit.edu • 937-255-3636 x7479

## A Center of Excellence for Acquisition Test and Evaluation

The Office of the Secretary of Defense (OSD) Scientific Test and Analysis Techniques in Test and Evaluation Center of Excellence (STAT T&E COE) within AFIT's Graduate School of Engineering and Management was established in 2012 to promote the use of scientific and statistical methods, especially design of experiments and reliability growth, in developing rigorous, defensible test plans and in evaluating their results. STAT T&E COE's formation was a result of actions by Congress and the OSD that included the reestablishment of the Deputy Assistant Secretary of Defense for Development Test and Evaluation (DASD(DT&E)); the push for more scientific rigor in testing from the Director of Operational Test & Evaluation (DOT&E); Assistant Secretary of Defense; and the signature of DASD (DT&E)'s STAT in T&E Implementation Plan by the service component T&E executives and DOT&E.

### Improving T&E Throughout the DOD

Through direct partnership with 25 ACAT I programs, research collaboration with the academic community, and focused training (see figure below), the STAT T&E COE improves the efficiency and effectiveness of the T&E planning execution, and analysis capability for the entire Defense T&E community. The STAT T&E COE provides effective and efficient test results to properly inform leaders, advocates the importance of understanding "how much testing is enough?" and ensures that test plans can be evaluated by decision makers on a quantitative basis. These strategies are expected to significantly improve both the short and long term outcomes of major acquisition programs.

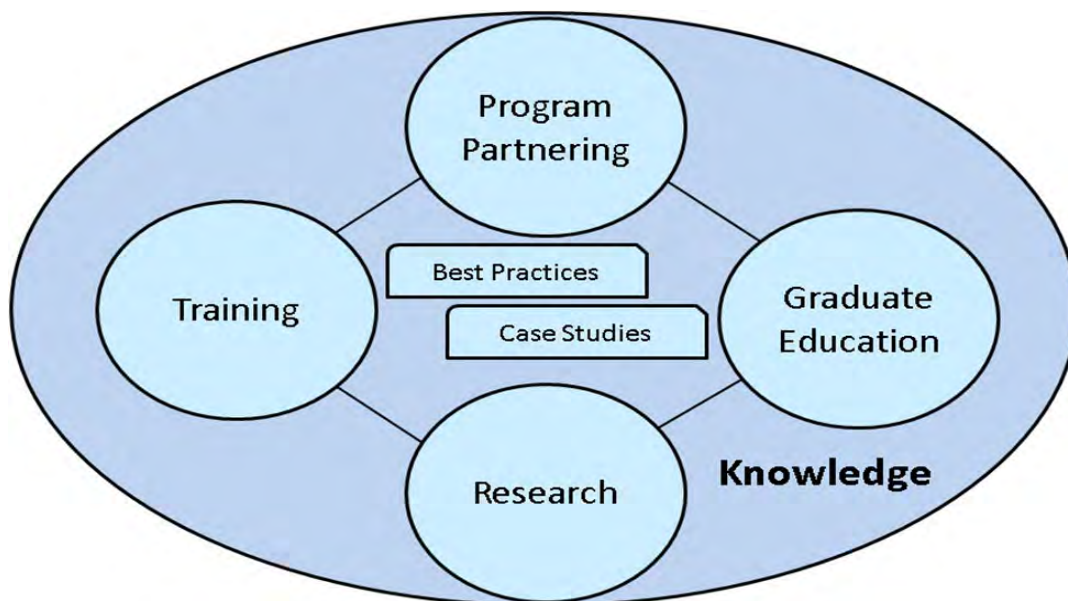


AFIT's STAT T&E COE serves ACAT I programs across the DOD.

Surveys of the initially supported ACAT I programs indicate that their partnerships with STAT T&E COE are providing significant value to their test and evaluation planning efforts.

### Expanding the T&E Knowledge Base

The STAT T&E COE leverages test and evaluation efforts across AFIT, and informs related graduate education programs. As applied technical approaches are developed by STAT T&E COE's T&E experts, these proven approaches are codified into best practices and case studies to share with the larger test and evaluation community. In addition, technically challenging, relevant topics appropriate for student theses are identified through the STAT T&E COE's interactions with major weapons and automated information systems acquisition programs. These potential thesis topics are then presented for consideration within the graduate school's faculty-led, student-driven research program.



STAT T&E COE activities synergistically improve the T&E knowledge base.

#### *CONTACT*

Dr. Darryl Ahner  
Darryl.Ahner@afit.edu • 937-255-3636 x4708

## \$144M Fuel Cost Savings by Tankering for Mobility Airlift Forces



The practice of tankering for cost avoidance is an important technique used by commercial air carriers to reduce their operating costs. Maj Walter Lesinski, a graduate of AFIT's Advanced Study in Air Mobility program, examined the option of fuel tankering as a viable cost saving initiative within the Air Mobility Command (AMC), the USAF and the DOD.

Maj Lesinski developed criteria and model for AMC to estimate tankering cost savings for planned flights and conducted a proof-of-principle study using historical AMC airlift mission data. The model compares fuel costs of historical flights completed without tankering to the respective fuel costs of the same flights with tankering, and demonstrates potential tankering savings of up to \$111 million per year. The model also enables AMC to determine if a planned flight should consider tankering, and if tankering is used, it estimates the total dollars saved in cost avoidance for that flight.

The United States Transportation Command (USTRANSCOM) adopted Maj Lesinski's model in June 2012 for Tanker Airlift Control Center flight managers to use for Afghanistan cargo missions as part of a multi-year USTRANSCOM Joint Distribution Process Analysis Center research agreement through the Center for Operational Analysis. USTRANSCOM was able to leverage Defense Logistics Agency (DLA) source cost for fuels to enable even greater savings than originally estimated.

Maj Lesinski's operationally relevant research directly led to a cost avoidance averaging nearly \$12 million per month since implementation and approximately \$144 million annually to the Air Force and DLA. His research was sponsored by the AMC's Fuel Efficiency Office.

### *CONTACT*

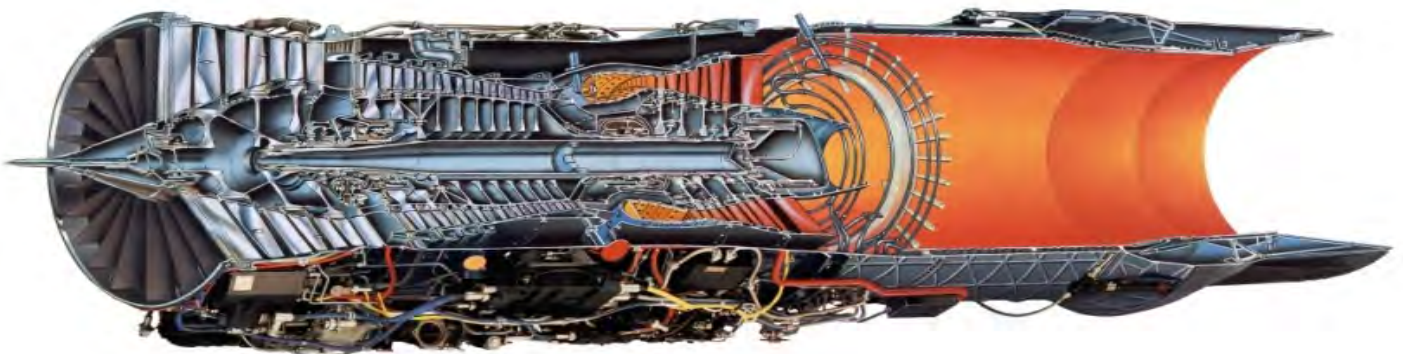
Dr. Alan Johnson  
Alan.Johnson@afit.edu • 937-255-3636 x4703

## Speeding Up the F100-229 Jet Engine Repair Process

Researchers at AFIT's Center for Operational Analysis (COA) and analysts at the Air Force Materiel Command, Studies and Analyses division (AFMC/A9A), have partnered together to provide a statistical engineering solution to identify slowdowns and bottlenecks in the repair network.

An adequate supply of F100-229 engines, which power the F-15 Eagle and late-model F-16 fighter jets, is vital to meet the operational demands of the Air Force. This supply is limited by government and inventory cost considerations, and new requirement calculations indicate a pending shortage of available engines. Without action, the Air Force would need to spend millions of dollars to increase supply. Fortunately, at current supply levels, availability can be improved by reducing turnaround times across the F100-229 repair network.

The team at AFMC/A9A built a simulation model to mimic and capture the actions of the real-world repair network. COA researchers then developed the methodology to explore the network using Design of Experiments, which identified the variables in the network that drive the balance of available engines. The simulation results were then programmed into a spreadsheet-based decision support tool. Program managers can use this information to explore cost-effective actions and configure the repair network to mitigate slowdowns in the areas that need it most.



Cutaway Image of the F100-PW-229 Jet Engine

### *CONTACT*

Dr. Raymond Hill

Raymond.Hill@afit.edu • 937-255-3636 x7469

## 3-D Laser RADAR for Next Generation Targeting Sensors

Electro Optical/Infra-Red (EO/IR) targeting sensors rely on passive illumination of the target area and are commonly employed on aircraft such as the F-15, F-16, A-10, B-1 and B-52. While these sensors are highly capable and provide a tremendous tactical advantage on the battlefield, they have inherent limitations in many applications. For ranging purposes, traditional EO/IR sensors rely on the addition of an active illumination designator. A key limitation of the active designator is it only provides ranging to a specific point in the target area at any given time.

Maj Brian Neff, a June 2013 Department of Electrical and Computer Engineering doctoral graduate, and his AFIT adviser, Dr. Stephen Cain, researched next generation targeting sensors that will likely incorporate three-dimensional (3-D) Laser Detection and Ranging (LADAR) technology which will allow for highly accurate ranging to all points within the scene simultaneously. Additionally, due to the active illumination nature of this type of sensor, the user is not dependent on passive forms of illumination or the natural heating and cooling of the targeted scene.

Maj Neff's research, sponsored by the Air Force Office of Scientific Research, developed new algorithms for estimating the range to multiple surfaces in a scene while simultaneously removing blurring that is caused by atmospheric turbulence. This capability can be applied to 3-D LADAR to detect targets hidden by camouflage, foliage or various other obscurations. His work also proved that the use of 3-D imaging presents solutions to challenging problems that are not feasible with 2-D imaging.

This research is valuable for many high priority applications in addition to targeting. By incorporating this technology onto refueling aircraft, it may be possible to conduct safe refueling in visually obscured environments. The multiple surface ranging algorithm could also be utilized in conjunction with tracking algorithms to conduct autonomous aerial refueling. Furthermore, safe landing of rotary wing aircraft in brown out conditions is yet another highly sought after capability that is brought closer to reality with this research. Through accurate ranging to multiple surfaces in each image pixel, the operator can see through the dust being kicked up and detect the obstacles or terrain below.

Ultimately, this body of research will lead to significant improvements in target recognition capability for future remote sensors.

### *CONTACT*

Dr. Stephen Cain  
Stephen.Cain@afit.edu • 937-255-3636 x4716

## Effects of Stereoscopic 3D Digital Radar Displays on Air Traffic Controller Performance

AFIT researchers have developed a revolutionary, patent-pending 3-Dimensional Air Traffic Control display system that provides immediate visual representation of vertical as well as horizontal aircraft separation that significantly improves controller accuracy and efficiency.

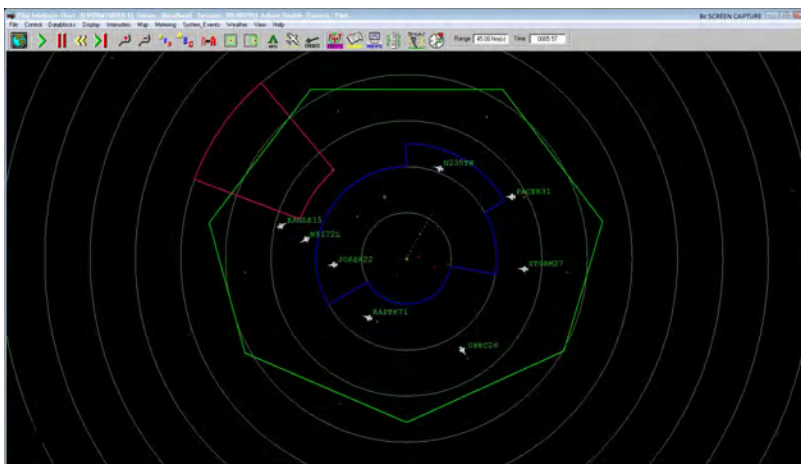
Today, air traffic controllers are responsible for directing air traffic based upon activity depicted on 2-Dimensional (2D) radar displays. Such displays present an aircraft's horizontal separation in two dimensions utilizing range rings while providing speed, altitude, and direction in textual form which requires deciphering and arithmetic to determine vertical separation. Controllers must continuously develop and refine "mental models" to detect potential conflicts while simultaneously executing plans of action to ensure safe separation is maintained. With nearly a 100% increase in traffic expected within the next decade, controller ability to rapidly interpret spacing and maintain awareness for longer durations will become increasingly important to flight safety.



Researchers 1LT Santana and MSgt Russi analyze 3D air traffic control settings prior to start of experiment with Air Force Controllers from Keesler AFB.

Since vertical separation is as imperative to flight safety as lateral separation, an intuitive design for determining vertical spacing without tedious mental model creation is critical to reducing controller workload and improving efficiency. To explore this and related problems Lt Col Brent Langhals and Dr. Michael Miller established an Air Traffic Control Display Lab to develop a stereoscopic (3D) radar workstation simulator.

The simulator was field-tested with 35 USAF controllers. It presented a view similar to traditional radar displays, (i.e. top-down), however, it depicted altitude through the use of 3D stereoscopic disparity, permitting vertical separation to be visually represented. This patent pending technology allows controllers to retain the familiar 2D representation of lateral separation, but also provides intuitive depth perception to quickly assess vertical separation. Results from this research have been shared with the Federal Aviation Administration and may influence the next generation of air traffic control display design.

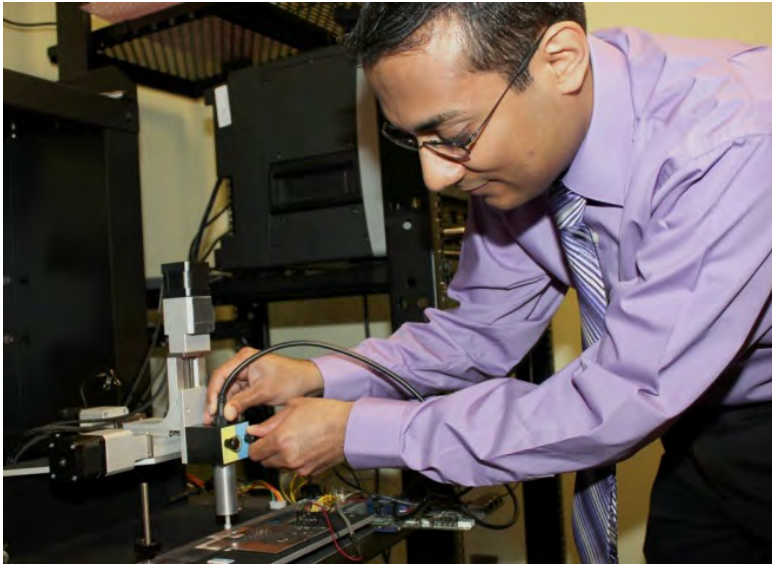


Screenshot of current Air Traffic Control display.

*CONTACT*  
Lt Col Brent Langhals  
Brent.Langhals@afit.edu • 937-255-3636 x7402

## Analyzing Electronic Data Protection Systems

Computing systems have become increasingly ubiquitous and complex in our modern age. From mobile devices to online banking and social networking, we constantly communicate and operate through networked computers. At the same time, a myriad of technologies have arisen to protect the increasing corpus of sensitive electronic information from unauthorized access. Examples include smart cards used in mobile computing, bank cards, and access control cards, and self-encrypting hard drives used in more traditional IT environments. In spite of these efforts, weaknesses in these protection technologies still exist.



**CCR research engineer sets up equipment to collect and analyze electromagnetic waves unintentionally emitted by a SIM card.**

Researchers at AFIT's Center for Cyberspace Research (CCR) have been investigating the effectiveness of these protection technologies and are developing and analyzing techniques that may be deployed to counter adversarial exploitation measures. Two recent efforts include research for the Department of Homeland Security to bypass the password locking mechanisms of Subscriber Identity Module (SIM) cards, and research to access the encrypted data on self-encrypting hard drives. SIM cards store mobile network authentication information along with text messages and phone book contacts. They are protected by two passwords, a personal identification number (PIN), and a PIN unblocking key. Self-encrypting hard drives protect data stored on

the drives from unauthorized access and also require an authentication code to unlock. CCR researchers are studying whether or not electromagnetic waves emitted by embedded microcontrollers on these devices leak enough information to bypass the password protection mechanisms.

This research will help DOD and other federal agencies collect the necessary evidence to prosecute cyber criminals and prevent terrorist attacks while providing more robust security solutions for future devices.

*CONTACT* (for pages 16 & 17)  
Dr. Robert Mills  
Robert.Mills@afit.edu • 937-255-3636 x4527

## New Labs Advance Cyber Research Capabilities

AFIT's Center for Cyberspace Research (CCR) is educating and equipping students to defend the US against cyber threats by advancing research capabilities with two new cyber laboratories: the Wireless Exploitation or WiX lab and the Hardware Reverse Engineering (RE) lab.

The recently completed WiX Lab advances student education and DOD-focused research in wireless security technology. The lab includes a radio frequency (RF) shielded room to exclude electromagnetic and RF interference (EMI/RFI) and to contain radiating signals from high-emission devices inside the enclosure. It is stocked with an array of advanced equipment for creating and analyzing wireless signals, including key components of 2G, 3G, and 4G cellular communications networks.

The Hardware RE Lab offers students, faculty, and research engineers the capability to evaluate the security of embedded systems. Embedded systems are electronic systems which utilize special purpose computers to run embedded software for specific control or data processing applications. Many familiar items fall into this category, including vehicle control systems, network routers, and mobile devices. The Hardware RE Lab includes an advanced solder rework station for removing tiny integrated circuits from circuit boards, a robotic manipulator arm for precisely maneuvering tools and automating experiments, equipment to observe the unintended electromagnetic emissions of electronic devices, a diode laser station for injecting faults into embedded systems in a controlled manner, and a high-performance computing cluster for running newly developed data and signal processing algorithms. Students are already using the new equipment and facilities to investigate security weaknesses in mobile messaging protocols and implementations.



**CCR researchers explore the new robot's capabilities. This robot has a greater range of motion, better accuracy and increased repeatability than CCR's other systems, enabling more powerful modeling of electromagnetic signals.**

Cyberspace can be categorized into two realms: a physical realm and a logical realm. The physical realm includes "hardware", electronic circuits and the associated electromagnetic (EM) signals they create and process. The logical realm includes "software", the ordered set of instructions or logic which tells a computer what to do. These labs are dedicated to researching the interplay of these two realms to assure secure operations and communications throughout cyberspace.

## Laser Lethality Modeling

Dr. Glen Perram in the Department of Engineering Physics, is leading a 5-year multi-university research program entitled, “Merging Hyperspectral Imagery and Multi-Scale Modeling for Laser Material Interactions” to better understand laser weapon system impacts.



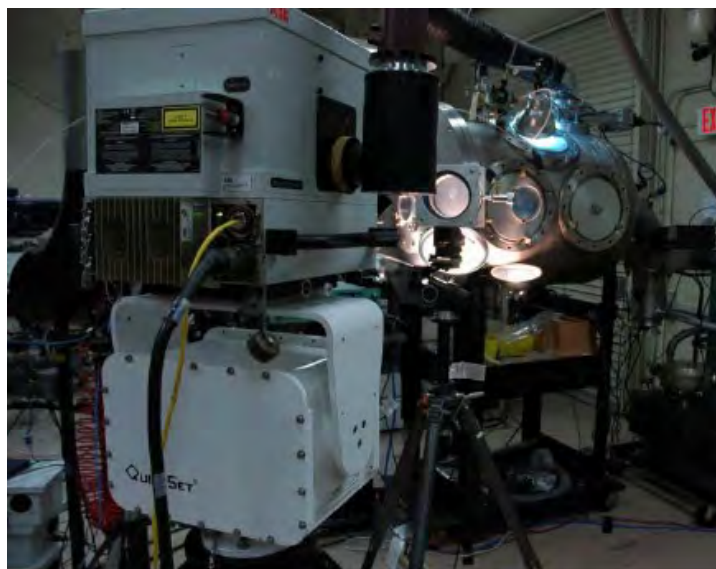
**Figure 1. Solid state laser irradiation of fiberglass.**

Laser weapons place a narrow beam of light on a distant target to inflict damage. Laser device powers of more than 100 kilowatts are typically required for most military missions. The effectiveness of high energy laser weapon systems to render a target nonfunctional depends in part on laser target materials interactions. Typically, the laser will dwell on the target for a few seconds to inflict thermal damage. The graduated effects of a laser weapon allow for the destruction, denied usage, degraded performance or delayed deployment of the target.

AFIT is evaluating the potential of imaging Fourier Transform Spectroscopy for monitoring thermal decomposition and combustion in the gas plumes generated by laser irradiation of surfaces containing carbon or hydrocarbon materials.

Figure 1 shows a solid-state laser irradiating a fiberglass sample to induce thermal decomposition. With sufficient energy deposited, spectacular combustion can occur in the gas plume above the surface. The propagation of the laser through these evolving gas plumes, the heat released in exothermic gas phase reactions, and changes to surface oxidation kinetics impacts the required dwell time to destroy a target.

The infrared spectra from the gas plume can be analyzed to determine temporally evolving temperature and concentrations of the combustion products. By adding fast framing hyperspectral imagery to the diagnostic, movies of the combustion products are developed, revealing the mechanisms and rate limiting processes involved in the laser induced damage. Lightweight, carbon reinforced polymers, painted aluminum alloys, and graphite materials exhibit widely varying phenomenology. Predictive damage models for these materials based on empirically informed, physical modeling are in development.



**A Fourier Transform Spectrometer viewing laser damage under vacuum conditions.**

### CONTACT

Dr. Glen Perram  
Glen.Perram@afit.edu • 937-255-3636 x4504

## Aerodynamic Characterization of an Air-to-Air Missile with Computational Fluid Dynamics

The US Air Force continually seeks to improve the survivability and lethality of its air superiority systems. In recent years, several converging trends have generated interest in the development of small, extremely agile multi-role missiles. The extreme maneuverability of these agile missile systems exposes them to unconventional aerodynamic environments that are not well understood.

Recent AFIT graduate, Capt Timothy Cleaver, has reduced the technical risks of developing new agile missile systems by undertaking a thorough and reliable characterization of the aerodynamic environment associated with their extreme flight profiles. He utilized a DOD-developed Computational Fluid Dynamic (CFD) tool, known as Kestrel, to predict the aerodynamic forces and moments generated by a concept missile geometry through a complete range of representative flight conditions. Capt Cleaver provided additional analytical rigor and breadth of applicability to his analyses through judicious use of Design of Experiments (DoE) principles.

The CFD simulations of the missile geometry were able to predict induced side forces and yaw moments on symmetric configurations at intermediate angles of attack, such as those observed in AFIT subsonic wind tunnel results. At transonic Mach numbers, the CFD estimates of in-plane forces were comparable to benchmark, semi-empirical prediction tools. Finally, computational estimates of pitch moment indicate that the concept missile may be statically unstable at intermediate angles of attack. The above observations, together with the extensive aerodynamic data collected by Capt Cleaver, provide invaluable feedback to the system developer who must take these performance characteristics into account when designing the integrated aerodynamic and attitude control systems featured in these next generation missiles.

Capt Cleaver's research was recognized with the 2013 Chancellor's Award, the highest AFIT award for master's level research. His thesis project was sponsored by Lockheed-Martin Missiles and Fire Control (LMMFC) in support of the Air Combat Command's Small Advanced Capability Missile program. Future phases of the research program will investigate several challenging aerodynamic effects associated with the novel control mechanisms employed by LMMFC's Cuda system in order to achieve unprecedented maneuverability and lethality.



Capt Timothy Cleaver (center) receives the Chancellor's Award from Dr. Todd Stewart (right) and past dean of the AFIT Graduate School of Engineering and Management and current President of the AFIT Foundation, Dr. Robert Calico (left).

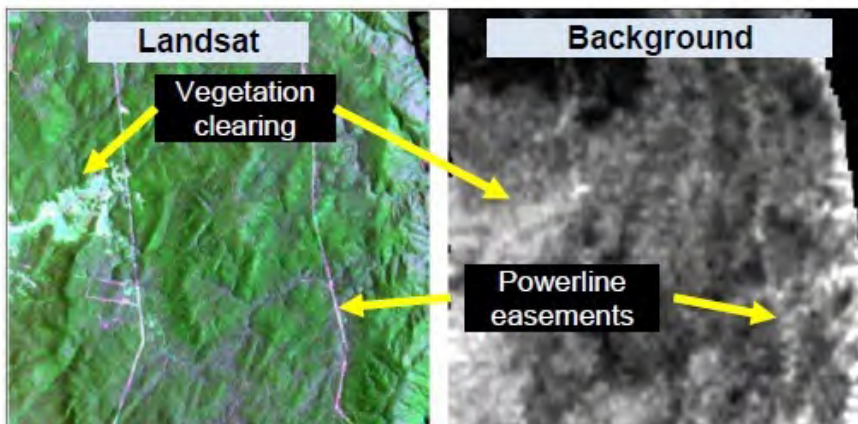
### CONTACT

Capt Christopher Martin

Christopher.Martin@afit.edu • 937-255-3636 x4403

## AFIT Helps DTRA Locate Radiation Anomalies

In April 2012, AFIT was awarded a three to five year basic R&D grant by the Defense Threat Reduction Agency (DTRA) to study how optical sensors could be used to help identify anomalous radiation sources such as leaks or hidden nuclear materials. DTRA is seeking new methods for quickly estimating background radiation levels from natural and/or known man made gamma ray and neutron sources in large urban environments to aid in the detection and location of anomalous radiation sources. Current methods are capable of modeling radiation levels with very high precision, but require extensive and cumbersome data input files with very long computational processing times. Previous work has demonstrated the effect of the environment on measured background radiation levels (see Figure 1), and suggests a potential for integrating optical sensor data with radiation sensor data to improve results.



**Figure 1.** The attenuation effect of vegetation on natural background radiation (potassium in this case) is depicted in these images. The clearing of vegetation in the Landsat image on the left clearly correlates to increased potassium radiation levels measured in the right image. (From Bierwirth, P.N., Aspin, S.J, Ryan, P. J., & McKenzie, N.J., "Gamma-ray remote sensing of soil properties in a forested area near Batlow," Proceedings of the 9th Australasian Remote Sensing Conference) 1998).

correlations between gamma ray measurements conducted over the US by the US Geological Survey and 7-band Moderate Resolution Imaging Spectroradiometer (MODIS) data. Data was also collected around the AFIT complex using a portable ORTEC Detective gamma ray and neutron detector coupled with reflectance measurements using an Analytical Spectral Devices Fieldspec Pro spectrometer. The goal was to determine if any correlation exists between spectral measurements and natural background radiation.

A current major focus of the project is developing scene models based on available data from other sources such as Geographic Information System (GIS) layers including geologic maps, terrain, surface cover type, road network, vegetation, and 3-D building models. In the absence of existing GIS layers, the data from the hyperspectral imager would be analyzed with special software to automatically create GIS layers, then coupled with radiation survey data to predict the background radiation distribution. The estimation and prediction of the expected background will be helpful in finding anomalous point, line and small area sources while minimizing

The AFIT team, consisting of faculty members Drs. David Bunker, Christoph Borel, Amy Magnus and Mike Hawks, is partnered with Dr. Graham Walford, a radiation sensor expert from the University of Tennessee, Knoxville. Over the course of the project, this team will lead the design and validation of gamma ray spectrum estimation algorithms that integrate optical and radiation sensor collections into high resolution, multi-modal site models for use in radiative transport codes.

During the first year, cadets from the US Air Force Academy worked with an AFIT research assistant to investigate

the number of false alarms due to known natural and man-made radiation sources such as radiological medical facilities and industrial users of radiological sources. Existing sensor data will be used to estimate the locations and source strengths of radiological sources which will then be compared with Bayesian estimation model outputs. Figure 2 depicts an example of fast generation of 3-D geometry based on spectral, GIS, and LIDAR data.

An important element of the project involves development of fast methods to estimate the gamma ray and neutron backgrounds. One possible path is to automatically generate input geometry from imagery, GIS, Voxelpedia and/or LIDAR measurements for established

nuclear transport codes such as Monte Carlo N-Particle (MCNP) code. However, runs for large urban areas usually require the use of super computers. Therefore, AFIT will also investigate adapting simpler and faster radiative transport methods such as the extended radiosity method which is used in many computer graphics rendering programs and promises potential real-time estimates. These simple methods could be used to predict radiation backgrounds in real time as sensors are taking data on moving or stationary platforms. Figure 3 shows a volumetric rendering of an urban environment that could be used in a radiative transfer model.

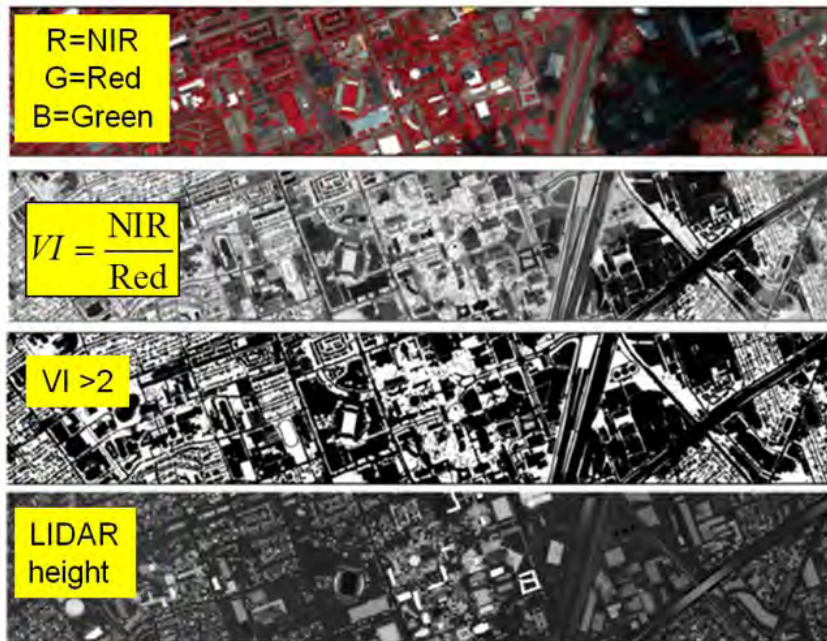


Figure 2. Hyperspectral data (top image) can be combined with automated vegetation detection (2nd & 3rd images) and building heights obtained from LIDAR (bottom image) to quickly model urban scenes.



Figure 3. Notional urban environment for simulated gamma-ray emissions.

*CONTACT*

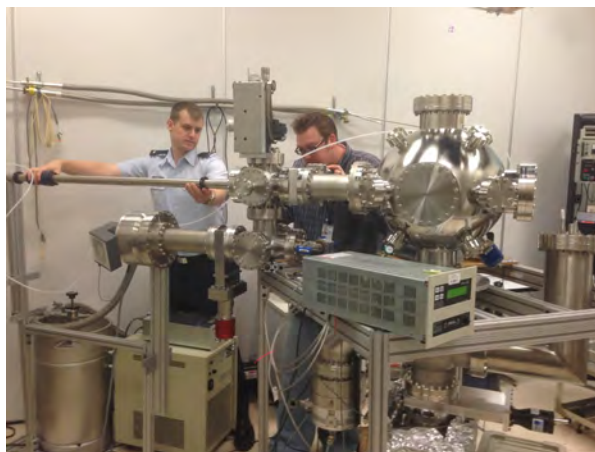
Dr. Christoph Borel-Donohue  
 Christoph.BorelDonohue@afit.edu • 937-255-3636 x4957

## Investigations of Nuclear Materials

If terrorists know that the nation has the capability to detect and identify devices and perpetrators - so that the “return address” can be determined - deterrence is enhanced accordingly.

*- Advisory Panel to Assess Domestic Response Capabilities for Terrorism Involving WMD*

A multidisciplinary research effort is underway at AFIT to develop and characterize well-structured actinide crystals to aid the nation’s nuclear deterrence and non-proliferation efforts. Studies of the actinide crystals, which include compounds of thorium or uranium, may open pathways for understanding the effects of nuclear material production and aging on the nuclear material’s structure – information that is critical for identifying the material’s origin. The studies may also yield new detection methods for neutrons and open the door to proliferation resistant nuclear fuel.



**Dr. Dave Turner, post doctoral researcher, and graduate student 1Lt Joshua Reding, prepare the sample loading and sputtering chamber of the AFIT Characterization and Photoemission Spectroscopy System (ACPESS).**

In collaboration with the Air Force Research Laboratory’s Sensors Directorate and their specialized Solvothermal lab, the research is based upon a liquid growth technique that allows for crystal growth of a very high quality and structure. The growth technique is a well understood method for quartz crystal growth, but offers many challenges when employed for actinide crystal growth. The present effort is oriented on the growth of thoria (thorium dioxide) crystals, and if successful will be eventually used for production of uranium based crystals. The goal is to obtain crystals with a high degree of uniformity and structure, providing characteristics that can be reliably measured and consistently applied.

Measurement of the crystal structure also offers new challenges being addressed in AFIT’s high vacuum spectroscopy laboratory. A unique instrument is under development that allows for cleaning (via noble gas sputtering) and a suite of experiments to be performed on the samples while being held in a single high vacuum environment. The vacuum environment is required for analysis, since the surface of actinide materials is known to be sensitive to environmental elements, such as oxygen. Experiments such as low energy X-ray diffraction, angle-resolved X-ray spectroscopy, photo-electron emission spectroscopy, and ultraviolet photo-spectroscopy will provide important insight into the crystal structure.

Further analysis of the thoria and uranium based crystals will be accomplished using multiple radiation sources, including neutrons and electrons. These measurements with radiation sources hold the key to evaluating the possible relevance of these crystals to a wide variety of applications and studies associated with nuclear deterrence. These applications include an integrated uranium based neutron detector that is not affected by other radiation (such as gamma rays), studies of signatures related to fuel processing and aging of nuclear fuels, and the use of thoria fuel pellets as an alternative, proliferation resistant nuclear fuel source.

### *CONTACT*

Dr. James Petrosky  
James.Petrosky@afit.edu • 937-255-3636 x4562

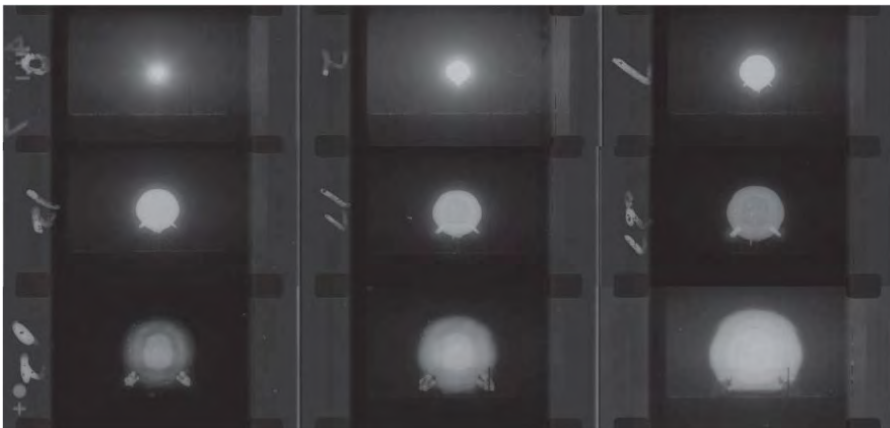
## Nuclear Test Film Analysis

AFIT faculty and students in the Department of Engineering Physics have partnered with researchers at Lawrence Livermore National Laboratory (LLNL) to collaborate in the area of nuclear test film analysis.

Throughout the 1950s and 60s, the United States filmed over 200 atmospheric nuclear tests. Approximately 7,000 of these films represent irreplaceable and unique data that has been foundational to our understanding of post-detonation physics over the past 60 years, and are still critical for validation and verification of modern nuclear weapon effects codes used by Defense Threat Reduction Agency (DTRA) and US Strategic Command (USSTRATCOM). Recently LLNL began an extensive effort using modern computer technology to scan these films into a high-resolution, digital format, preserving the film data far into the future and also providing researchers the opportunity to study the films using computational methods that were not available when the films were first recorded.

Five graduate students in the Nuclear Engineering program and two doctoral students in the Applied Physics program have chosen research projects related to reanalysis of the nuclear films. The scope of these projects range from revalidation of historical models given higher resolution data to the development of new models and theories based on data fusion between the films, other sensors used to monitor the tests, and advanced computer simulations. Recent results include improved accuracy of current fireball timing models by a factor of two, improved ability to estimate nuclear yields from films, new ways that fireball light output can be correlated with the weapon design characteristics, and new methods for automating the processes for analyzing nearly 24 million frames of film.

As the project moves into the second year, we are coordinating with potential sponsors from the DTRA, the AF Nuclear Weapons Center, and the National Nuclear Security Administration (DOE). Funding for the entire project now exceeds \$500K over the next three years, which will support the scanning and analysis of the films at LLNL and additional research by AFIT students and faculty.



The panels to the left show the development of the early time fireball taken using high speed film cameras (~2500 frames per second). Images like these are digitized using a film scanner at Lawrence Livermore National Laboratory. Modern computer methods are then used by AFIT students to identify features such as light output intensity, fireball radius, and apparent temperature.

### CONTACT

Dr. John McClory

John.McClory@afit.edu • 937-255-3636 x7308

## Software Model Simulates Wear Mechanisms in 3D Configurations

A new software model is under development at AFIT to enable cost-effective material selection and testing for aerospace, automotive or weapon systems involving bearings, gears, brakes, slippers, or even rocket test tracks. Many system components are subject to mechanical wear, defined as “the removal of material volume through some mechanical process between two surfaces,” which must be accounted for in the design and testing processes. AFIT researchers, under the direction of Dr. Anthony Palazotto, Distinguished Professor of Aerospace Engineering, are particularly focused on the mechanical wear related to high-speed sliding between two surfaces.

Experimental mechanical wear studies are very expensive, and these costs have prevented the collection of necessary data required to fully characterize 3D wear phenomena. The research team is developing an Abaqus Finite Element Model (FE) of mechanical wear, that would enable prediction of wear under different scenarios, significantly reducing necessary field experimentation.

AFIT’s 3D FE high velocity wear model assumes that sliding wear can be represented by the relative movement of two objects where one object impacts an asperity (representing surface roughness) between the two surfaces (Figure 1). For comparison to the experimental case described below, the upper object is called the slipper and the lower object is referred to as the rail. The computational results from the model can be extrapolated to estimate the average sliding wear per unit of area.



Figure 1. Time sequence of wear development using AFIT’s 3D FE high velocity wear model of the collision of a slipper (upper object) with an asperity on a rail (lower object).

It has been found that pressure developed in many of the collisions can be so great that a material shock wave results. This requires an equation of state characterized by phase change and therefore the need for nonequilibrium thermodynamics. The result of the sliding motion may create a melt zone at the surface interface which can add significantly to the overall mechanical wear.

An experiment run at the Air Force Experimental Facility at Holloman Air Force Base (AFB) that is affected by the wear phenomenon studied within this research is shown in Figure 2. The results of this research are being extended with the help of Holloman AFB to other experimental runs.



Figure 2. The setup at Holloman Experimental Test Track consisted of 4 rocket powered sleds. AFIT’s research methodology was instrumental in assisting Holloman AFB to achieve the world land speed record of Mach 8.5 for the rocket sled.

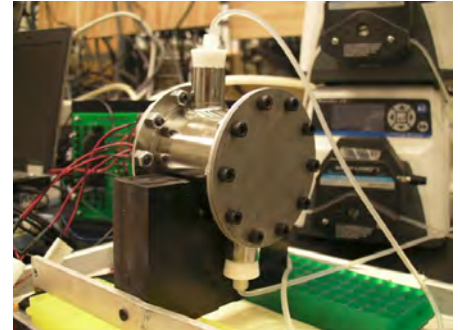
### CONTACT

Dr. Anthony Palazotto  
Anthony.Palazotto@afit.edu • 937-255-3636 x4599

## Environmentally Friendly, On-Site Water Treatment

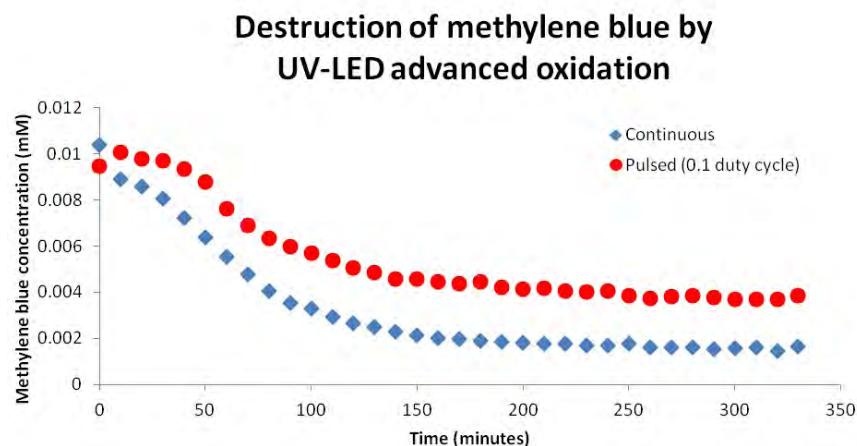
Improved techniques for treating municipal wastewater or drinking water disinfection at forward deployed sites are being investigated by AFIT faculty, Lt Col LeeAnn Racz, Dr. Michael Miller and Dr. Michael Grimaila. This research, in partnership with the United States Environmental Protection Agency's National Homeland Security Research Center, uses ultraviolet energy from light emitting diodes (LEDs) and hydrogen peroxide to generate reactive hydroxyl radicals that can destroy chemicals of concern.

Accidental or intentional releases of chemicals often result in waste that must be disposed. Frequently, municipal wastewater treatment plants are looked to as a way to dispose of the liquid waste. However, municipal wastewater treatment plant operators may not accept the waste if there is a risk of it disrupting the plant's performance. The new LED technique enables these undesirable chemicals to be destroyed by oxidation on-site so that the remaining wastewater may be safely sent to the wastewater treatment plant. AFIT's research also includes constructing a model to understand the interaction of LED drive characteristics on the observed phenomena in order to predict their performance under varying conditions.



UV LED reactor apparatus

At the same time, they are investigating how this LED technology can be used to treat drinking water. There are many reasons why drinking water should be treated on-site, especially at forward-deployed sites. Although bottled water is officially intended as the source of last resort, it is often the primary source of drinking water at these sites. Bottled water must be delivered to these sites at great expense, and generates tremendous waste. Therefore, water disinfection at the point of use could reduce vulnerability, expense, and health hazards of deployed personnel. This study is evaluating the effectiveness of this LED technology to treat drinking water inexpensively.



**Figure 1. Methylene blue concentration after exposure to hydroxyl radicals produced by ultraviolet LED advanced oxidation in both continuous and pulsed configurations.**

### CONTACT

Lt Col LeeAnn Racz

LeeAnn.Racz@afit.edu • 937-255-3636 x4711

## New Space and Terrestrial Science Curriculum Launched

In response to a request from the Air Force Director of Weather, a new Applied Physics track has been established supporting a hybrid space and terrestrial science curriculum to meet current AF weather educational and operational needs. Over the past 20 years, the Department of Engineering Physics has offered a highly successful and responsive Master's of Science in Applied Physics program that supports weather officers through a 21-month, Space Physics track that provides a concentration in solar and space sciences. The program is maintained in the Space Physics track and continues to be offered in addition to the new hybrid track.

A faculty committee led by Assistant Professor, Dr. Ariel Acebal, evaluated the request and developed the new track servicing Atmospheric and Space Sciences (ASC 8FSY) which received rapid AFIT approval. Dedicated manpower for the terrestrial core was provided with the addition of two faculty members, Lt Col Robert Wacker and Maj Keven Bartlett. Lt Col Wacker specializes in microwave remote sensing and atmospheric dynamics, and Maj Bartlett focuses on fine-scale numerical weather prediction and modeling of dust and pollution transport.

This new track, inaugurated in less than nine months after the initial request, integrates the studies of the air and space environments and provides a deep understanding of the operational effects. Students complete five courses each in space physics and atmospheric sciences, while their thesis research addresses topics of current interest to AF Weather and their primary operationally supported units.

Thesis research in both tracks is focused on prioritized topics supplied from the AF Weather community. Current student research addressing space physics needs include automated sunspot detection and classification using solar dynamics observatory imagery, and the effects of high temporal cadence solar and geomagnetic observations of Air Force Weather Agency's (AFWA) operational ionospheric model. Topics dealing with terrestrial science include validation of AFWA Joint Ensemble Forecast System Point Probability Forecasts, comparison of Ensemble Mean and Deterministic Wind Forecasts for Strategic Airlift Fuel Planning, use of Dual-Polarized Doppler Weather Radar Parameters to Aid in Forecasting Lightning Initiation at Kennedy Space Center, and an investigation of the dependence of Numerical Weather Prediction Model Tropical Cyclone Position Forecast Errors on Initial Position Analysis Errors.

With a curriculum supporting the full range of terrestrial and space weather—mud to sun—AFIT's got you covered!

### *CONTACT*

Dr. William Bailey

William.Bailey@afit.edu • 937-255-3636 x4501

## AFIT's Center for Cyberspace Research Designated as NSA Center of Academic Excellence in Cyber Operations



The National Security Agency (NSA) and the United States Cyber Command (USCYBERCOM) designated the Air Force Institute of Technology as a National Center of Academic Excellence (CAE) in Cyber Operations for the period 2013-2018. The goal of the CAE program is to strengthen national security by promoting higher education and research in cyber operations with a particular emphasis on technologies and techniques related to specialized cyber operations (e.g., collection, exploitation, and response) and producing a growing number of professionals with cyber operations expertise in various disciplines. The program identifies institutions offering a cyber curriculum that has deep technical foundations in computer science, computer engineering and/or electrical engineering, and interdisciplinary research with extensive opportunities for hands-on applications through cyber labs and exercises.

After a rigorous application and screening process, AFIT's Master's of Science degrees in Cyber Operations and Cyber Warfare were recognized as graduate level curricula satisfying NSA's rigorous academic requirements and program criteria. These degree programs are offered by the Department of Electrical and Computer Engineering along with significant support from the Center for Cyberspace Research (CCR).

The CAE-Cyber Operations Program supports the President's National Initiative for Cybersecurity Education (NICE): Building a Digital Nation and complements AFIT's 2009 designation in NSA's earlier CAEs in Information Assurance Education and Research Programs.

### *CONTACT*

Dr. Robert Mills

Robert.Mills@afit.edu • 937-255-3636 x4527

## AFRL-AFIT Colloquia

A new AFRL-AFIT colloquium series was held in 2013, to further enhance the AFRL-AFIT partnership. The initiative was the brainchild of former AFRL Commander, Maj Gen William McCasland, and AFIT Chancellor, Dr. Todd Stewart, who were seeking ways to mitigate the restrictions on travel to non-DOD conferences. The AFRL-AFIT colloquium series featured four events, one each for the traditional Air Force domains of Air, Space and Cyber and one focused on Human Performance. The “Autonomous and/or Cooperative Air Operations” colloquium was the first of the four scheduled events this summer. Each colloquium event featured a host of presentations by AFRL and AFIT researchers, and was available to multiple AFRL locations via VTC. The event served as a great opportunity for personnel from both organizations to become more familiar with other’s research efforts and to expand their network of contacts for future efforts.



**Dr. James Overholt, 711th Human Performance Wing Senior Scientist for Autonomous Systems gives the opening remarks at the Human Machines Colloquium on September 10, 2013.**



**AFIT PhD student, Capt Jason Bindewald, presents his research on Design of Automated Systems to Aid in User Task Completion.**

## Excellence in Education Honorees

*Ohio Magazine* recognizes outstanding teachers at colleges and universities around the state. The following AFIT faculty members were recognized in the December 2012 issue:

- Ariel Acebal, PhD, Department of Engineering Physics
- Jeffrey Weir, PhD, Department of Operational Sciences
- Edward White, PhD, Department of Mathematics and Statistics

## Dr. Willie F. Harper, Jr.

Dr. Willie F. Harper, Jr. joined AFIT as an Associate Professor in the Department of Systems Engineering and Management. Prior to AFIT he served on the faculty at Auburn University and the University of Pittsburgh.



Dr. Harper's research uses biotechnology for environmental applications related to water quality and ongoing projects focus on microconstituents, biosensing, and resource recovery. He has published numerous peer-reviewed articles and has been honored with several awards, including the 2011 Pennsylvania Water Environment Association Professional Research Award, 2006 NSF Faculty Early CAREER Award and the 2013 Fulbright Scholar Award. As a Fulbright scholar, Dr. Harper developed and evaluated process configurations that can be used at wastewater treatment plants to recover a wide range of useful products, including clean water, biofuels, fertilizer, methane, pharmaceutical chemicals, and biodegradable plastics. The benefits will be balanced against risks related to safety, cost, and negative environmental impacts. Multi-objective optimization will be used to identify processes or inputs that should be targeted to maximize the broader social and economic impacts. His work was done in collaboration with researchers at the Tokyo University of Agriculture and Technology.

## Military Faculty Sequential Tour Officer Option

Maj Milo Hyde, Assistant Professor in the Department of Electrical and Computer Engineering, and Maj Matthew Robbins, Assistant Professor in the Department of Operational Sciences, are the first faculty members selected for a 3-year follow on tour through AFIT's military faculty Sequential Tour Officer (STO) option. The STO option helps to maximize return-on-investment for select military faculty by providing stability to the military member and research program, and improved opportunities for academic advancement.

Since their arrival at AFIT in 2010, Majs Hyde and Robbins have demonstrated superior academic faculty performance, achieving high scholarly performance and research productivity. They have both established well-funded, steady research programs benefiting their students and the DOD organizations/agencies supported by the research.

The STO option is made possible by a Memorandum of Agreement signed in March 2012 between AFIT, the Secretary of the Air Force Acquisition Career Management and the Headquarters Air Force Personnel Center Acquisition Assignments Branch. STO assignments will also assist in the challenging task of maintaining the highly specialized skill set mix in the AFIT military faculty pipeline needed to maintain academic rigor and essential accreditations.

### *CONTACT*

Col Brian Tom

Brian.Tom@afit.edu • 937-255-3636 x7112

## Lt Gen Andrew E. Busch



Lt Gen Andrew E. Busch earned his commission in 1979 as a graduate of the U.S. Air Force Academy. In 1990, he graduated from AFIT with a master's degree in Acquisition Logistics Management. His research focused on two-level maintenance. The maintenance community's focus is now on its successor, Repair Network Integration (RNI). RNI covers the same issue of how to disperse repair locations, capitalize on resource efficiencies and manage risk to war plans. This is exactly what Gen Busch was immersed in when he completed his master's thesis.

General Busch is a logistician with a core background in fighter aircraft maintenance. As an Aircraft Maintenance Officer, he served in a variety of sortie production

roles and commanded three maintenance squadrons and a maintenance wing. He also has experience in supply, transportation and acquisition issues at the wholesale

*"AFIT delivers critical skills for the Air Force. My opinion on that is unchanged from when I was a student at AFIT, to now as a Lieutenant General as I watch the volume of young men and women who go through AFIT today."*

logistics level. General Busch currently serves as the Vice Commander, Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio. The command employs some 80,000 people and manages \$60 billion annually in research, development, test and evaluation, while providing the acquisition management services and logistics support required to develop, procure, and sustain Air Force weapon systems.

## Dr. Mark M. Derriso

The road to success for recent doctoral graduate, Dr. Mark M. Derriso, was a long and hard one with its beginnings taking root at AFIT. He began working as a lab technician within the Department of Aeronautics and Astronautics, then later as an engineer in the Structures Division at AFRL. Dr. Derriso's years as a lab technician were invaluable to his career. He worked closely with faculty and students and supported them with their research. He attributes his ability to connect the concepts he learned as a technician to the theory he learned as a student. Dr. Derriso's doctoral research focused on how to improve autonomous systems for increasing the efficiency and effectiveness of Air Force operations. The research was directly connected to his work at AFRL where he managed programs on state awareness and real-time response.



*"AFIT was a great experience for me. The most important part is the research, making sure it is unique, and that you are making a contribution to the field."*

Dr. Derriso is currently the Technical Advisor for the Warfighter Interface Division in the 711th Human Performance Wing at AFRL where he leads the core technical area of decision making for air, space, and cyber domains. He continues to maintain a strong connection with AFIT, funding research for current students and working on joint research projects with faculty.

## Class of 1963 Celebrates 50th Reunion

Alumni from the 1963 class of Electrical Engineering, Graduate Guidance and Control Option (GGC63) visited AFIT as part of their 50th reunion activities. While at AFIT, the group toured AFIT's Space Lab, Materials/Structures Lab, the Wind Tunnel, and the Center for Cyberspace Research (CCR).

The GGC63 program was originally a Master's in Electrical Engineering. They studied feedback control systems with texts written by AFIT Professors John J. D'Azzo and Constanstine H. Houpis. Classes and makeshift labs were held in the venerable old Building 125, a couple of blocks north of current AFIT campus. As the program moved forward over two years, the studies evolved into a concentration on orbital mechanics. Simultaneously, they were personal witnesses to the evolution from analog to digital computer technology and the attendant applications to equations of motion in space. When the program name changed, the 1963 graduates were awarded the degree of Master's of Science in Astronautical Engineering.

Through the years, each class member has taken advantage of the excellent technical knowledge gained at AFIT and the multitude of advanced applications that evolved. Their AFIT education has proved invaluable to each member of the class in many diverse areas, from research, development, test and evaluation through systems acquisition and program management. Both in the Air Force and during later careers in private industry, each member of the class contributed his special expertise to our mutual national objectives.



## AFIT's First Graduates from the Republic of Singapore



International students, Maj Edmund Pek and Maj Kerwin Teong, are AFIT's first graduates from the Republic of Singapore. Maj Pek received a Master's of Science in Logistics and Supply Chain Management and was a distinguished graduate. Maj Teong received a Master's of Science in Systems Engineering.

**Left to right: Maj Kerwin Teong, Dr. Todd Stewart, Maj Edmund Pek, and Maj Jason Png. The Republic of Singapore students present Dr. Stewart with a gift of the inverted Chinese character meaning good fortune/prosperity arriving.**

## Selected Large Awards for FY13

### \$750K - National Geospatial Intelligence Agency

Overhead Persistent Infrared (OPIR) R&D  
Dr. David Bunker

### \$350K - Air Force Sustainment Center

Research, Analysis and Transition Support  
Dr. Alan Johnson

### \$665K - TRICARE

Joint Integrated Electronic Health Record (iEHR) Initial  
Operating Capability Support  
Dr. Rusty Baldwin

### \$348K - Defense Threat Reduction Agency

Polarimetric HIS for Improved Radioactive Source Detection  
Sensitivity and Localization Accuracy  
Dr. Kevin Gross

### \$450K - AFRL

AFRL Strategic Analysis of Lab Infrastructure  
Dr. Jeffrey Weir

### \$330K - Air Force Medical Support Agency

Air Emissions Characterization from Open Burning and  
Incineration of Military Waste in Afghanistan  
Lt Col Dirk Yamamoto

### \$414K - National Science Foundation

Increasing the Federal Cybersecurity Workforce through  
Graduate Education and Research  
Dr. Rusty Baldwin

### \$325K - OSD DOT&E

Advanced Test and Evaluation in Support of the DOD Test  
and Evaluation Enterprise  
Dr. Raymond Hill

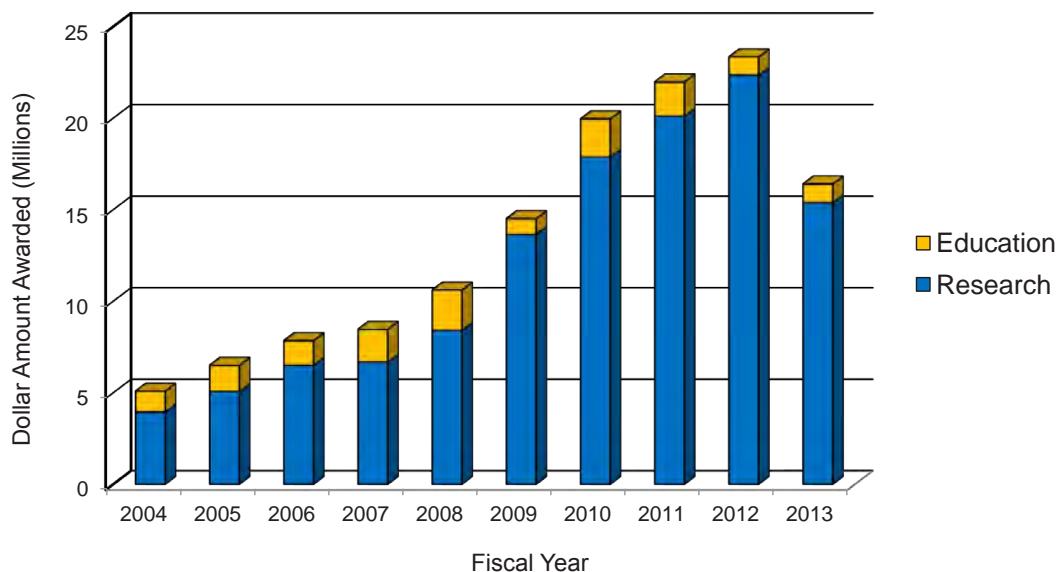
### \$358K - OSD TRMC

Advanced Test and Evaluation in Support of the DOD Test  
and Evaluation Enterprise  
Dr. Raymond Hill

### \$308K - Air Force Command and Control Integration Center

Joint Aerial Layer Network Development of the Command  
and Control Measure of Effectiveness Development  
Dr. Darryl Ahner

## New Award History FY04-FY13



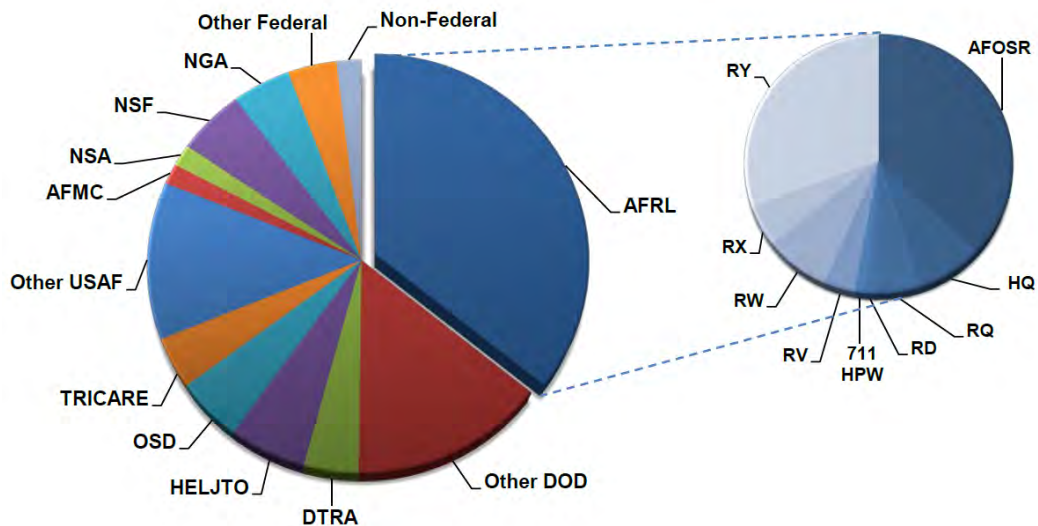
## New FY13 Awards to Academic Departments and Research Centers

DEPARTMENT	Newly Awarded Research Projects		Newly Awarded Education Projects		Total FY13 Newly Awarded Projects		Total FY13 Research Expenditures
	#	\$k	#	\$k	#	\$k	\$k
Mathematics & Statistics (ENC)	8	362	-	-	8	362	475
Electrical & Computer Engineering (ENG)	57	4,463	4	856	61	5,319	6,096
Engineering Physics (ENP)	43	4,911	1	28	44	4,939	5,846
Research & Sponsored Programs (ENR)	1	16	-	-	1	16	-
Operational Sciences (ENS)	13	2,713	1	90	14	2,803	5,782
Systems Engineering & Management (ENV)	15	567	-	-	15	567	1,435
Academic Affairs (ENW)	-	-	1	5	1	5	-
Aeronautical & Astronautical Engineering (ENY)	52	2,370	2	30	54	2,400	5,801
<b>TOTAL</b>	<b>189</b>	<b>15,402</b>	<b>9</b>	<b>1,009</b>	<b>198</b>	<b>16,411</b>	<b>25,435</b>

CENTER	#	\$k	#	\$k	#	\$k	\$k
Advanced Navigation Technology (ANT)	23	1,402	-	-	23	1,402	1,732
Center for Cyberspace Research (CCR)	8	1,371	4	829	12	2,200	1,640
Center for Directed Energy (CDE)	23	2,448	-	-	23	2,448	2,273
Center for Operational Analysis (COA)	13	2,713	1	90	14	2,803	5,741
Center for Space Research and Assurance (CSRA)	11	1,031	-	-	11	1,031	2,827
Center for Technical Intelligence Studies & Research (CTISR)	6	1,257	-	-	6	1,257	1,173
<b>TOTAL</b>	<b>84</b>	<b>10,222</b>	<b>5</b>	<b>919</b>	<b>89</b>	<b>11,141</b>	<b>15,386</b>

Note: Total research expenditures reported include institutional cost sharing, which is not included in newly awarded projects. Numbers reported to the ASEE and NSF research expenditure surveys vary somewhat due to differences in definitions. All Center funds are also included in departmental funding.

## Sponsors of FY13 Projects



\*Pie chart on the right shows breakdown by AFRL Technology Directorates.

## Enrolling at AFIT for Graduate Studies

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

Our automated application system at <http://www.afit.edu/en/admissions/index.cfm> provides immediate application information to the Office of Admissions and there is no application fee. Because of our highly automated admission processes, the Office of Admissions usually renders an admission decision within 21 days.

Prospective students will join a robust and energetic student body focused on learning and research. The Accreditation Board for Engineering and Technology (ABET) accredits all of our eligible engineering programs. Students usually finish their master's programs within two years and the doctoral programs within three years. Enrollment averages around 700 full- and part-time students with a student to faculty ratio of 5:1. In academic year 2012-2013, 277 master's and doctoral degrees were awarded to 206 AF officers, 5 AF enlisted, 16 sister services, 40 civilians, and 10 international military officers. Our campus consists of 8 buildings, 23 class laboratories, 67 research/laboratory areas, and the D'Azzo Research Library.

For more information, visit [www.afit.edu/EN/admissions/index.cfm](http://www.afit.edu/EN/admissions/index.cfm).

## AFIT Internship Opportunities

Internship opportunities are available for undergraduate and graduate science, technology, engineering, and mathematics (STEM) students through the Southwestern Ohio Council for Higher Education (SOCHE). Students have the opportunity to work at AFIT through the Summer Internship Program, the Student Research Program, or both. Students benefit both academically and financially by working in state-of-the-art laboratories with top professionals in their field. Additionally, they can use this experience for senior projects, cooperative education and graduate research. AFIT receives the benefit of top students who bring new energy and ideas to the research projects.

For additional information regarding AFIT internship opportunities, please visit: <http://www.socheinern.org/>.

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Editorial Office:  
AFIT/ENR  
2950 Hobson Way  
WPAFB, OH 45433-7765  
Telephone: 937.255.3633  
Fax: 937.656.7139  
Email: [research@afit.edu](mailto:research@afit.edu)

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