2016 ANNUAL REPORT

AIR FORCE INSTITUTE OF TECHNOLOGY

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT

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MESSAGE FROM THE DEAN

AFIT is a very special place. As the Air Force's Graduate School, AFIT is engaged in both degree-granting programs and professional continuing education. We deliver this mission through AFIT's four schools, namely the Graduate School of Engineering and Management (AFIT/EN), the Civil Engineer School (AFIT/CE), the School of Systems and Logistics (AFIT/LS), and, lately, the School of Strategic Force Studies (AFIT/EX). AFIT/EN is presently the only degree-granting arm of AFIT, but in our usual agility and responsiveness, some of the other schools may be called upon to offer customized degrees in one form or another at some point. AFIT remains ready to serve the needs of the Air Force.

Going far back into history, records and testimonies show that as goes the military, so goes the nation. From the expansion of empires, the defense of existing nations, and the creation of new free nations to the advancement of democracy, the military is always somewhere in the spectrum of operations. It is in this context that I challenge my colleagues in the Graduate School of Engineering and Management to be adept at playing flexibly in the three cultures within which we operate; namely, the Military Culture, the Federal Government Culture, and the Academia Culture. We accomplish this through a judicious interplay of Research, Instruction, and Consultation. As the common cliché goes, we teach what we research and we research what we teach. Our research centers are active participants in this integrated approach. We are constantly in a state of exploration, investigation, experimentation, and exploitation of new research initiatives to serve and advance the interests of the US Air Force, the Department of Defense, and the Nation. We are making strategic investments in laboratory hardware, operational software, and people-ware. We just took delivery of high-end additive manufacturing equipment (aka 3D Printer) to move forward with new initiatives for product development to support national defense. A team of AFIT faculty are co-editing a Handbook of Additive Manufacturing, the first of its kind on the market. This demonstrates our intellectual leadership of the emerging field. We are also strategically developing and expanding initiatives in game-changing areas, including hypersonics, directed energy, autonomy, and data analytics. The year 2016 saw a record-breaking level of AFIT's sponsored research accomplishments. I am delighted to see this new record and I look forward to what the future holds in terms of upward trajectory of research sponsorship. On the people side, we have re-energized our faculty development program. It is my fervent belief that the more we invest in our people, the more we can accomplish for our nation. A fully-empowered faculty is the recipe for accomplishing the integration of research, instruction, and consultation. Under new leadership, novel faculty-development program offerings involve partnering with neighboring institutions for multi-lateral exchanges of best practices.

As we reflect on the accomplishments of 2016 with pride, the faculty, students, staff and I continue to align our core missions of education, research, and consultation with national priorities. We are exploring advancements in delivering graduate education, leveraging research pursuits to provide relevant contributions to solve pressing problems of today, and reaching out to external stakeholders in addressing the needs of the global society. We will continuously march toward our vision of excellence in defense-focused, research-based advanced STEM education to better serve the United States Air Force and our total nation. I invite you to join us in this exciting adventure.

With the best AFIT regards to all,

Adedeji B. Badiru, Ph.D., PE
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CENTER SPOTLIGHT: Center for Directed Energy

AFIT's Center for Directed Energy

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The Air Force Institute of Technology (AFIT) has been at the forefront of DoD-directed research, education, and innovation since the Air Force first envisioned using high energy lasers and high power microwaves as weapon systems. The Center for Directed Energy (CDE) was established as a cross-disciplinary center to conduct sponsored research which would influence the evolution of directed energy. CDE focuses on Research, Education, Innovation, and Collaboration.

Research: CDE research is focused on solving DoD research problems related to directed energy technologies and DoD applications. The center develops models and software that are used primarily for educating, consulting, and advising.

Education: CDE is focused on educating the next generation of Directed Energy (DE) professionals. Pre-service and in-service short courses are offered with an emphasis on research to support education. In conjunction with the graduate school and the Engineering Physics Department, CDE offers rigorous academic programs in the DE associated technologies. Additionally, CDE offers unique co-op and internship opportunities that challenge participants to expand their knowledge and apply it to related real-world scenarios.

Innovation: CDE contributes to the DoD directed energy community through robust research solutions and delivery of software addressing critical DoD needs related to directed energy. CDE researches many areas that will enable or influence new sources of laser power, including chemical, gas, and solid state lasers with advanced active tracking and adaptive optics capabilities.

Collaboration: CDE develops Modeling and Simulation products for researchers and war fighters through collaboration with a diverse group of partners in the DoD and directed energy communities. One of CDE's major contributions is the development of software (HELEEOS and LEEDR) to more accurately model atmospheric.

For information on the Center for Directed Energy, or to sponsor a research project, please contact:

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CDE Vision Statement: "America's premier institution for creating government DE scientists & engineers while advancing the state of the art in DE through education and research."

CDE Mission Statement: The mission of CDE is to advance basic and applied research in DE enabling technologies and DE system concepts through experiment, modeling & simulation, and verification and validation. The results of this research provide the DoD DE community with educated personnel, new concepts, and scientific tools to maintain the technical edge of the fighting forces of the USA.

Airborne Aero-Optical Laboratory-Transonic (AAOL-T)

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CDE Research Engineer Matthew Krizo operating the AFIT Active Pointer Tracker during a data collection flight.

High energy laser weapons systems have the potential to completely transform air combat, and the Air Force has resolved to have laser weapons in service by the close of the decade. The Center for Directed Energy (CDE) is on the leading edge of advances and efforts to develop tactical airborne laser defense systems. An inbound enemy missile can come from any direction, however, high aircraft speeds result in air flow turbulence around and behind an aircraft that would prevent focused laser propagation across large distances. In order to overcome this fundamental challenge to realizing a useful laser missile defense shield, the CDE supports the endeavors of the Airborne Aero - Optical Laboratory-Transonic (AAOL-T).

This uniquely 'real world' aero-optical test platform demonstrates a multidisciplinary and highly collaborative research effort between academia and privateindustry. The laboratory consists of two Dassault Falcon 10 aircraft, privately owned by the University of Notre Dame, flying in close formation at Mach numbers nearing the speed of sound. During testing, the twin aircraft depart from Grand Rapids Regional Airport in quick succession, joining in formation with a separation distance of 50 meters at an altitude of about 30 thousand feet. Onboard one aircraft, the AFIT Active Pointer Tracker (AAPT), a system developed at AFIT specifically for transmitting a well-controlled green laser beacon through the turbulent region and precisely into the second aircraft. Onboard the second aircraft is a miniaturized laser beam steering turret and a suite of high speed electronics designed for the control and measurement of laser wave fronts. The laboratory flies a data collection mission of 2-3 hours before returning to Grand Rapids with up to a terabyte of wave front data, containing information about the air flow turbulence caused by the beam steering turret and the effectiveness of any techniques used to overcome the aero-optic effect.

View from the source aircraft during a data collection flight. The backside of the AFIT Active Pointer Tracker beam steering gimbal mirror is shown as it illuminates the Notre Dame beam steering turret with its green source laser at a distance of 50 meters.

Ground testing and alignment of the AFIT pointer tracker 2.5 Watt green laser to the Notre Dame AAOL turret at a distance of 150 meters.

Collecting aero-optic data in a true-to-life in flight scenario is critical to connecting Computational Fluid Dynamic simulations to wind tunnel testing, and wind tunnel testing to real world application. By combining these powerful design and experiment tools, the AAOL-T team is able to develop novel mechanical solutions for passive turbulent air flow mitigation and adaptive-optic solutions to put as much energy on target as possible. AFIT and the AAOL-T team continue to expand the capabilities of this research platform, pushing for longer separation distances, a wider range of laser beacon wavelengths and two-way laser propagation between the aircraft, in order to meet the goal of an effective laser weapons system in place by the end of the decade.

CENTER SPOTLIGHT: Center for Directed Energy

Atmospheric Characterization Using Time-Lapse Imaging

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Characterization of the atmosphere remotely, without deployment of physical sensors in and around the region of interest, is of value to the directed energy community. Traditionally, irradiance based methods such as scintillometry are used to measure strength of turbulence. However, irradiance based methods cannot be used over long, nearly horizontal paths through turbulence, since they suffer from saturation effects.

An imaging approach has been developed by the researchers at the Center for Directed Energy (CDE) to estimate turbulence strengths over such long paths. In addition to estimating turbulence, this method provides a ground truth measurement of refractive bending. The imaging based quantification of refractive bending can help to validate and improve fine-scale numerical weather prediction models by providing quantification of the vertical temperature lapse rate in the lower atmosphere. The vertical temperature lapse rate in the lower atmosphere is strongly influenced by the radiative properties of the surface. Thus it can change significantly with cloudiness, terrain, and changes in ground cover (e.g., snow). Yet it is only directly measured approximately twice a day with radiosonde balloon launches that are widely spaced geographically. It is currently difficult to capture the radiative nuances of partial cloudiness, terrain, and ground cover with numerical weather models. Thus if refractive bending observations were conducted with the imaging technique along with standard surface weather observations, the deduced temperature lapse rate could be used to increase forecast accuracy in the lower atmosphere. The sea level vertical refractive index gradient in the U.S. Standard Atmosphere model is $-2.7 \times 10^{-8}\ \mathrm{m}^{-1}$ at a wavelength of 500 nm. At any location, the actual gradient varies due to turbulence, local weather conditions, and time of day. The imaging approach enables estimation of the diurnal variations in refractive index gradient from the refractive bending measurements. This has never been investigated before.

An experiment was conducted at the Air Force Institute of Technology (AFIT) to demonstrate the imaging approach. From a ground floor window of a laboratory building at AFIT, images of Good Samaritan Hospital building were captured every minute by a Canon 40D digital camera, fitted with a 300 mm focal length telephoto lens. The camera system was mounted on a sturdy tripod and a cardboard shield was used to shade the tripod from direct sunlight. The 12.8 km (8 miles) path from AFIT to Good Samaritan Hospital is nearly horizontal, and for the most part about 60 m above ground. Figure 1 shows a schematic of the experimental setup and the elevation profile, along with sample daytime and night time images. Atmospheric turbulence caused the images to wander quickly, randomly, and statistically isotropically and changes in the average refractive index gradient along the path caused the images to move vertically

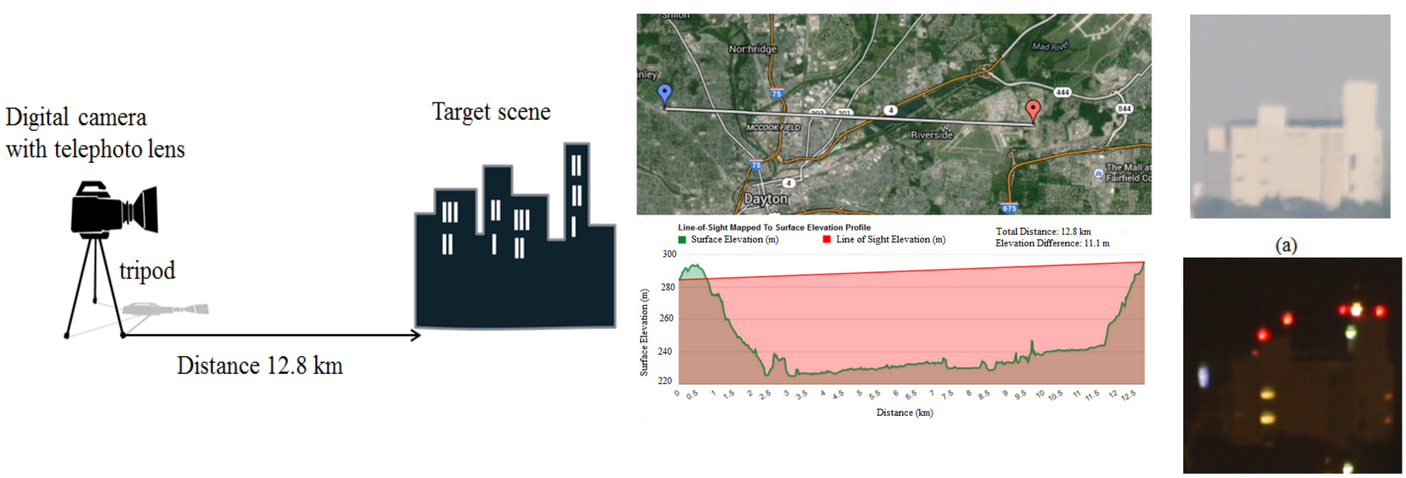

Figure 1: Time-lapse imaging experiment. (a) Experimental setup, (b) Elevation profile, and (c) Sample daytime and night time images.

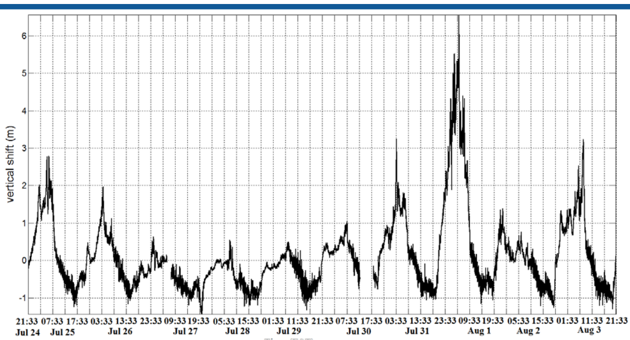

Figure.2: Apparent shift in hospital position over 10 days.

and more slowly. Correlation techniques were used to estimate the image shifts.

The slow, vertical drift due to refractive bending is proportional to the linearly weighted change in refractive index gradient along the path, with zero weight at the hospital. Figure 2 shows changes in the apparent hospital position from the evening of July 24, 2014 to the evening of August 3, 2014. Gaps in the profile indicate cloudy/ foggy periods where visibility was poor. The image motion over the course of a day varies from about a meter on some days to about six times as much on certain days. This corresponds to diurnal variations of 1.2 x 10^{-8} m^{-1} to 7.2 x 10^{-8} m^{-1} in the average refractive index gradient. The diurnal variation thus can be more than twice the standard atmosphere value for the gradient on certain days. The thermal inversion that develops during the night causes an apparent upward motion of the hospital during the night.

The night time movement is bigger on cloud-free, calm nights, such as July 31st when a strong, thermal inversion could develop. During the day, as the ground and the surrounding air starts warming up, the thermal inversion disappears and the hospital appears to move down. One interesting aspect of the plot is that the hospital appears to be almost at the same observed vertical position every afternoon, suggesting the refractive index gradient values are nearly the same each afternoon throughout the observation period. This can be expected as during the afternoon, the boundary layer is well mixed and the conditions are near adiabatic. A dip in the profile beyond the usual floor (~ -1 m) is seen in the early evening of July 27, 2014. This is due to the development of a superadiabatic condition caused by a strong moisture gradient near the surface following rain and a thunderstorm earlier during the day.

Turbulence strength, C_n^2 is estimated from the random component of image motion. The variances of random motion of different features/patches in the images are computed. The path-weighting functions for these variances depend on the size of the imaging aperture and the patch size in the image whose motion is being tracked. Figure 3 shows a set of path-weighting functions for different patch sizes. Knowledge of the variances and the corresponding path-weighting functions enables estimation of the path-weighted C_n^2. Since this method is phase-based, it can be used over long paths through turbulence. Figure 4 shows the C_n^2 estimates derived from the time-lapse imagery on two separate days. While the profile on July 29th shows a typical cycle of C_n^2 evolution, the profile on July 25th is different. A look at the observation data for that day explains the atypical behavior. The presence of cirrus clouds and light fog did not allow a pronounced C_n^2 drop at sunrise. Less cloudiness in the morning allowed for some ground heating and a mid-morning C_n^2 peak (~minute 300). More clouds—and even some light precipitation—occurred at midday, which forced an early afternoon minimum. Sunshine in after 2 PM allowed for the highest C_n^2 values of the day in the mid-afternoon around minute 550.

Estimates derived from the time-lapse imagery shows excellent correlation to meteorological conditions. In the future, additional turbulence parameters will be estimated by studying the differential motion of features of different sizes and separations in the images. The turbulences estimates will be compared to those obtained from standard measurement techniques, such as scintillometry.

This work is supported by the Air Force Office of Scientific Research (AFOSR) Multidisciplinary Research Program of the University Research Initiative (MURI) Grant.

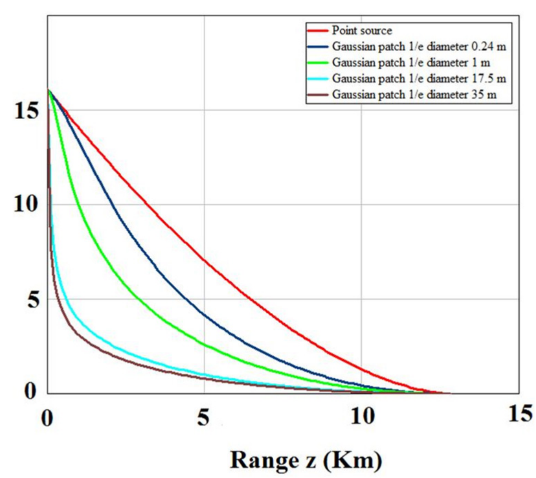

Figure 3: Path-weighting functions for estimation of C_n^2.

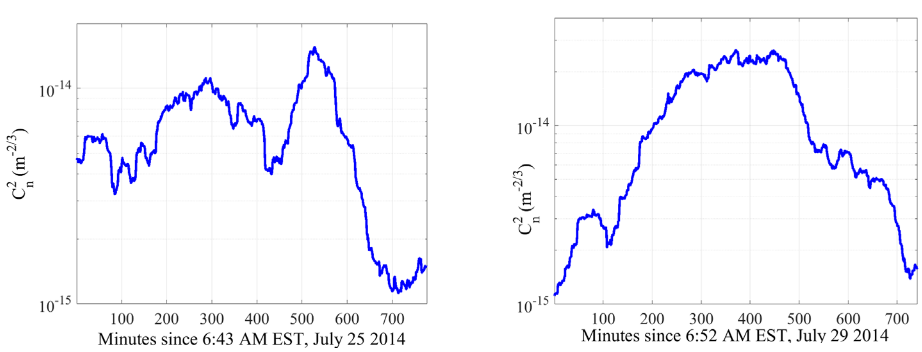

Figure 4: Estimates of C_n^2 for July 25, 2014 and July 29, 2014.

AFIT's CDE and Raytheon Launch CRADA with Student Research into Sensor Hardening Against Laser Weapons

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AFIT's Center for Directed Energy (CDE) has teamed with Raytheon Space and Airborne Systems of El Segundo, CA under a Cooperative Research and Development Agreement (CRADA) titled "Directed Energy (DE) and Remote Sensing Research, Development and Prototype Demonstration." The goal of this relationship is to identify, research, develop and rapidly field DE concepts and associated system components such as laser beam control, adaptive optics, and target identification and tracking systems. It combines the research expertise and experience of both organizations to provide technical solutions to national security needs in the areas of high-energy lasers (HEL's), atmospheric physics and remote sensing, as it also advances the organic staff expertise of both organizations through education and research in these areas.

The four objectives laid out for this CRADA are: (1) The unique expertise and capabilities of AFIT's CDE in remote sensing, atmospheric physics, adaptive optics, beam control, and algorithm and signature development are being leveraged to improve Raytheon's HEL simulations in areas of optical propagation and associated atmospheric effects, system design and performance estimates, and innovative sensor and beam-control designs. (2) The CDE and Raytheon are combining their respective expertise and computational capabilities for the development, test and operation of HEL beam-control hardware, laser communications and laser sensing systems. (3) AFIT curriculum development and instruction will be enhanced by Raytheon input as qualified Raytheon staff members may become AFIT instructors or thesis and dissertation advisors as appropriate. (4) Raytheon staff members have gained access to AFIT's degree programs as they may enroll in AFIT curricula, attend AFIT courses in-residence, conduct research at both AFIT and Raytheon facilities, and ultimately earn AFIT graduate degrees under this CRADA.

The first Raytheon employee to become an AFIT student is Mr. Jacob Wilson, who is seeking the Master of Sciences degree in Optical Sciences and Engineering in AFIT's Department of Engineering Physics. Mr. Wilson holds a Bachelor of Science degree in Physics from Wright State University, OH. He has already completed all required coursework for the degree in residence at AFIT, and is currently working on thesis research in the area of sensor hardening against HEL threats in El Segundo under the direction of Dr. Mitchell Haeri, Senior Engineering Fellow and Program Manager at Raytheon, and Dr. Michael Marciniak, Professor of Physics at AFIT.

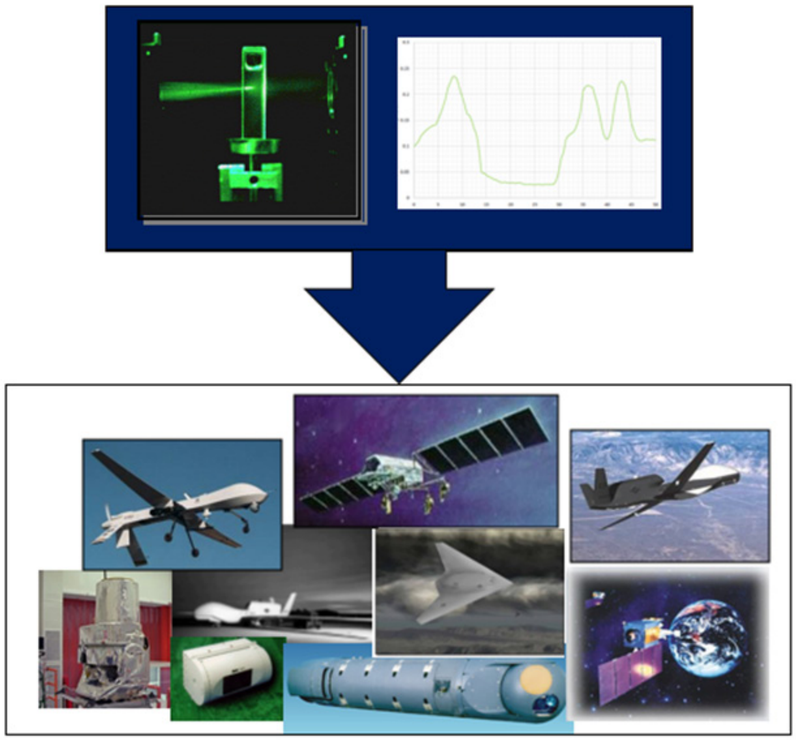

Figure 1: Experimental work on laser transmission through materials could be transitioned to weapon systems as optical filters. Photo Source: Dr. Mitch Haeri and Raytheon Space and Airborn Systems of El Segundo, CA.

Speckle Noise Mitigation to Improve Imaging

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When imaging a distant target, turbulence in the air can severely blur and distort the images. To return the images to near pristine quality, one can use a certain type of advanced optical system known as adaptive optics (AO). Adaptive optics use electro-mechanical components to correct the turbulence distortions, similar to how eyeglasses correct vision. However, because the turbulence changes over time, an AO system must measure and adapt to these changes.

To measure the turbulence effects, an AO system uses a wave front sensor (WFS). Such a sensor requires a beacon on the target, which is a light source that provides a reference wave. For non-cooperative targets, the AO system must create its own beacon on the target, and it usually does so by focusing a laser beam onto the target. The small laser spot reflects off the target's surface, providing light which travels through the air, allowing the WFS to estimate the air's turbulence effects.

Unfortunately, when the laser light reflects off the target's surface, something known as optical speckle results. Speckle causes bright and dark regions to form in the detector of the WFS, producing noise in the measurements. Unless mitigated, this speckle noise is quite strong, leading to large errors as the AO system attempts to correct the turbulence.

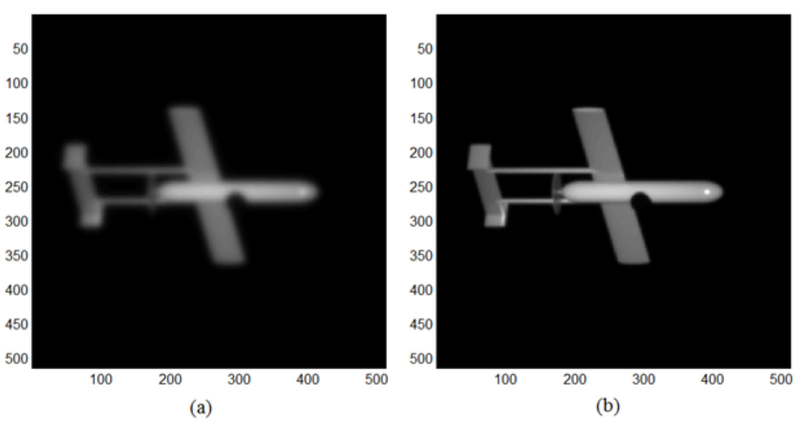

Figure 1: Example of the reduction in image blur that is possible with adaptive optics. Image (a) shows a distant UAV including significant blur due to turbulence. In image (b), much of that blur has been reduced by an adaptive optics system.

The purpose of this research is to quantify the speckle reduction achievable by shortening the coherence length of the beacon laser. So far, experimental results confirmed both that such coherence shortening does reduce speckle strength and that existing models can accurately predict this reduction, even for the somewhat unique conditions of common WFS's. Further, we created a new model for speckle mitigation and other optical coherence effects. It is rigorously based in theory and should find use well beyond this specific application. Future work will quantify speckle reduction via coherence shortening over a broad range of conditions. Further, we will conduct an experiment to validate the benefits to WFS's for the correction of turbulence effects.

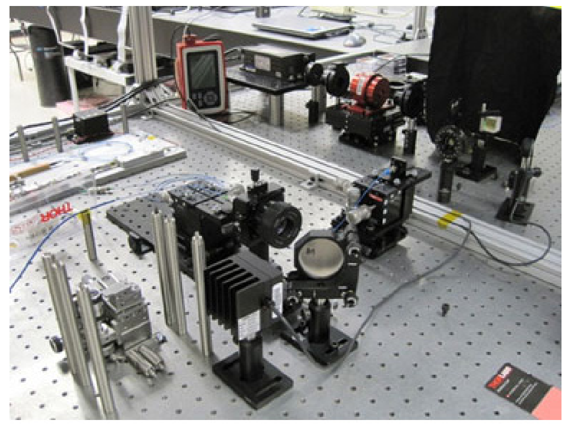

Figure 2: The experimental layout used to validate several models of speckle mitigation. Speckle is mitigated by shortening the coherence length of the light. This experiment replicates the conditions found in wavefront sensing scenarios. Results show that two of the three models are valid under such conditions.

CENTER SPOTLIGHT:
Center for Directed Energy

Rayleigh Beacon Development for the John Bryan Observatory

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A specialized and uniquely capable Rayleigh beacon system is being developed and added to the 24" telescope at the John Bryan Observatory. This system will measure three-dimensionally resolved atmospheric turbulence above the telescope. This project is investigating the deeper turbulence seen at lower elevations, but largely avoided by higher altitude mountaintop observatories. Building a better understanding of deep turbulence, plus a better understanding of imaging and laser propagation through this turbulence, is important to predicting the performance of all kinds of optical systems, military and otherwise, in such environments.

The Air Force Institute of Technology Center for Directed Energy, in collaboration with the Air Force Research Laboratory's Sensors Directorate, is developing and deploying a dynamically range gated Rayleigh beacon system to the Photometry Analysis and Optical Tracking and Evaluation System (PANOPTES) Quad Axis Telescope at the John Bryan Observatory. This telescope, pictured in figure 1, is a 24" Ritchey-Chretien (RC), with a unique four axis mount. An RC telescope has a wider aberration free field of view over a conventional telescope, at the cost of hyperboloid mirrors for both the primary and secondary. Fortunately for this project, this telescope was already in-place, and this project will be an upgrade to its capabilities. The four-axis mount enables the telescope system to track objects throughout the sky with no dead spots, whereas ordinary two-axis mounts typically have a dead zone along some axis.

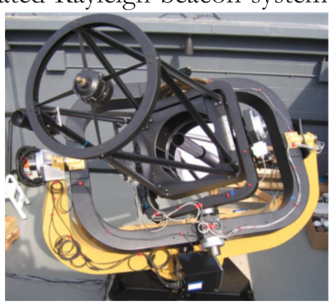

Figure 1. Photograph of the 24" telescope and quad-axis gimbals system at the John Bryan Observatory.

The Rayleigh beacon system measures turbulence in the atmosphere by transmitting a pulse of laser light into the sky above the telescope and collecting the light backscattered by air molecules at a set range from the telescope. The system achieves this by sending out a short pulse of light, and then triggering the sensor when the time of flight of the light pulse is correct for the range of interest. This requires both the laser pulse and the sensor shutter times to be very short (in the tens of nanoseconds). To profile turbulence along the path the timing is adjusted to move the apparent position of the beacon up and down along the telescope's line of sight; this is illustrated in figure 2.

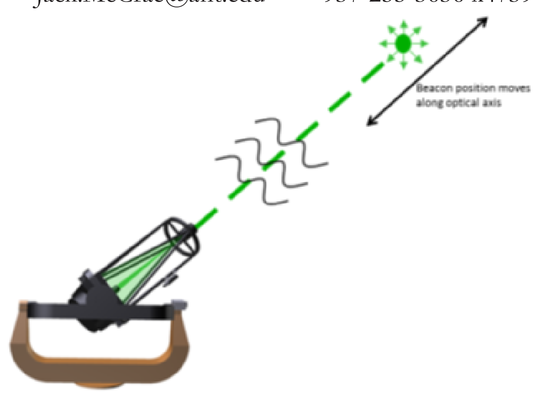

Figure 2. Photograph of the 24" telescope and quad-axis gimbals system at the John Bryan Observatory.

The system uses a Shack-Hartmann sensor to measure the distortion in the returned light caused by turbulence along the path between the scattering molecules and the detector. A Shack-Hartmann sensor consists of an array of tiny lenses, or lenslets, and a camera. If there were no distortions due to the atmosphere, the image on the camera would consist of an array of bright spots, each perfectly centered under one of the lenslets. It is the motion of these spots away from their center points which allows the turbulence to be quantified.

What makes this system unique is the timing and control system that produces the range gate for the Rayleigh beacon coupled with a laser beam launch system that is centered on the optical axis. The laser beam launch system is configured to produce a collimated beam at a desired beam waist size such that the range gate for collecting the backscattered light can be changed to be shorter or longer in time without the need to physically move the Shack-Hartmann wavefront sensor back and forth into a perfect focus point. What this allows for is the Rayleigh beacon control system to use preprogrammed timing changes on the range gate at specific intervals on a per pulse basis. The laser used is capable of producing strong enough pulses to receive return energy up to 200 Hz. This means that the system is capable of making up to 200 individual measurements per second from different integrated volumes.

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Diode Pumped Rare Gas Laser

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Laser weapon systems for strategic missions, such as missile defense and tactical missions including gunship operations, require very efficient, high power laser devices with low thermal loads. A typical tactical engagement involves focusing a high power (>100 kW) laser beam and maintaining at a small spot size (>10 cm) to damage, weaken, or destroy the target at distances of 1-10 km within a dwell time of ~10 s.

The quest for a high-power, electrically driven laser with excellent thermal management, lightweight packaging, and high brightness for tactical military applications may be realized with the recent advent of diode-pumped gas lasers. For example, the Diode Pumped Alkali Laser (DPAL) has been scaled to powers exceeding 1 kW and efficiencies of greater than 81%. Pumping a gas-phase medium with large diode arrays combines the best features of electrically driven lasers with the inherent thermal management advantages of a gas laser. The DPAL system is currently being scaled for missile defense applications. However, there are complications associated with the handling of the chemically aggressive alkali metal vapors. An analog system, the diode pumped rare gas laser (DPRGL), has recently been demonstrated by a multi-university research initiative (MURI), involving Emory University, AFIT, Tufts University, and Physical Sciences Inc. This system requires a low power, high-pressure discharge of rare gas mixtures such as helium and argon. In order to achieve large-volume and high-pressure plasma conditions, novel discharge approaches are necessary.

Mr. Ben Eshel, an AFIT civilian PhD student, has developed a micro-cathode sustained discharge array (MCSDA). This discharge uses a micro-hollow cathode discharge (MHCD) array as a plasma reactor, a source of high energy (>10 eV) electrons to feed a large-volume (>10 cm^3) DC-RF hybrid discharge. The MHCD consists of a three-layer substrate of two conductors sandwiching a dielectric. The electrons leaving the micro-holes have divergence angles of >25 degrees allowing a large-volume, homogeneous discharge to form above the DC plate.

Future work involves testing these arrays and optimizing the conditions required to produce the necessary rare-gas excited states in order to successfully demonstrate the laser weapon capabilities of the DPRGL system.

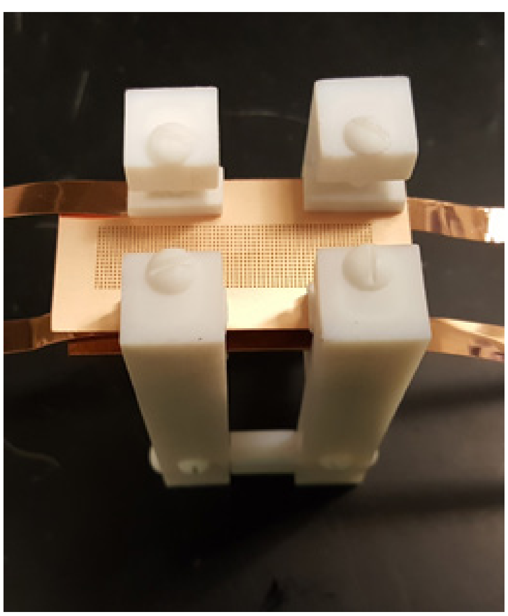

Figure 1: MCSDA before initial testing.
Photos provided by AFIT Lab 113 Bldg 644

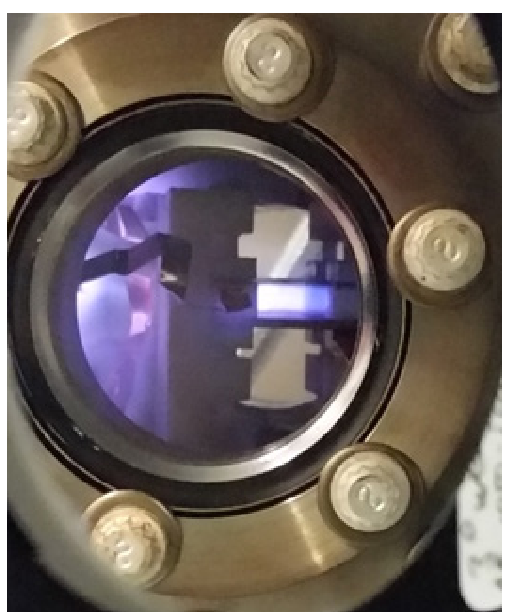

Figure 2: 10 Torr test of MCSDA showing a homogeneous plasma filling the volume (1 cm^3) between the plates.

CENTER SPOTLIGHT:
Center for Directed Energy

Advancing DoD's Third Offset Strategy: Validating AFIT's Joint Any-Weather Directed Energy Decision Aids

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Over the past year, Secretary of Defense Ashton Carter has been advocating our Nation pursue a Third Offset Strategy to ensure continued deterrence against adversaries seeking to exploit an asymmetric advantage. As Ms. Katie Lange so ably describes it, an offset strategy is focused on achieving and then retaining strategic advantage, "…finding the right combination of technologies and operational and organizational constructs to achieve decisive operational advantage."(1) A key component Ms. Lange highlights is Deep-Learning Systems. This category will include human tactical decision aids as well as fire control systems appropriate to light speed battle wherein, for example, high energy lasers (HELs) are used to defeat swarms of incoming hypersonic munitions. Such decision aids and fire control systems are being developed by AFIT are attentive to ever-present and ever-changing weather, which has impacted battle since earliest times. Using constantly updated surface observations and "big-data" numerical weather models, AFIT has been able to prepare tools for comparison with real-world HEL field tests, so the user can be confident the decision aid and fire control systems are validated, work, and perform as needed.

To evaluate expected directed energy weapon (DEW) system performance and usher in decision aids for speed-of-light engagement, the AFIT Center for Directed Energy (AFIT/CDE) has developed several modeling codes to simulate operating conditions. One of these codes, the High Energy Laser End-to-End Operational Simulation (HELEEOS), is the first DEW simulation package to fully incorporate National Weather Service numerical weather forecast data; correlated, probabilistic climatology; as well as an interface which accepts actual weather observations. By integrating such weather information, HELEEOS is strongly positioned to assess DEW system performance as well as variability/uncertainty in such assessments, whether it be forecasted for operations a week in advance or anticipated for future system engineering and development. A key activity in any software development effort is verification and validation the code is producing results that physically correlate with observation. With this in mind, AFIT recently participated in a joint effort with the High Energy Laser Division US Army Space and Missile Defense Technology Center (USASMDC), which is responsible for the High Energy Laser Mobile Truck Transport (HEL-MTT) Program.

In collaboration with the (USASMDC) team, Ms. Kathryn O'Connor—on temporary assignment to CDE—commenced a comparative assessment of a series of HEL-MTT related field tests results and HELEEOS calculations by carefully reviewing all ground test instrumentation data and actual HEL measurements. Using the test instrumentation data and ground test set-up information, Ms. O'Connor was able to initialize HELEEOS to realistically simulate test conditions. These parameters included beam power, shape and displacement at target, turbulence along the path, and atmospheric data. Much of the HEL test data was collected and analyzed by Scientic, a defense sciences company supporting the AMRDEC team in Huntsville, Alabama, using their Laser Beam Analysis and Diagnostics System (LBADS). LBADS uses a camera and power meter in order to collect, calibrate, and process data to create 2D and 3D false color images of the spot profile, as well as power in the bucket versus diameter of the spot. All of this information was useful for comparison with and evaluation of HELEEOS model outputs.

On close analysis of the HEL test data, Ms. O'Connor found two distinct classes of down-range, at-target laser beam profiles, both of which were well-modelled by HELEEOS. In the first class of scenarios, the prevailing wind at the test range was blowing off axis of the beam path by more than 10 degrees. As such, the wind was effectively blowing through the beam, negating any heating which otherwise occurs along a HEL path due to laser absorption by atmospheric aerosols. Such heating can lead to distortion of the beam and non-Gaussian (non-circular) beam profiles down-range at the target of interest. As shown in Figure 1, there indeed was little disruption along the path and a nearly ideal Gaussian-like profile at target, whether measured during the test or outputted by HELEEOS. In this particular example, the wind was 40º off the laser path. Both model and test equipment showed comparable laser intensity at target.

The second class of scenarios, depicted in Figure 2, is influenced by an interesting phenomena that changed the down-range, at target beam intensity profile. In these cases, the wind was blowing along the line of sight, within ±10º from the south. Now, the wind was no longer clearing the laser propagation path of super-heated air, which created evidence of thermal distortion of the laser beam and the intensity profiles at target. Upon comparison of the instantaneous peak powers associated with the results shown in Figure 2, both ground test and HELEEOS-calculated values are again very similar. This distorted beam pattern occurred for all tests in which the wind was almost directly along the line of sight of the beam.

In sum, these series of tests and their re-creation using the HELEEOS model show AFIT's HEL decision aids development efforts are well-grounded. These results are attracting great interest in the broader DoD HEL community as evidenced when Ms. O'Connor presented them at the recent, internationally-recognized Directed Energy Professional Society's System symposium.

REFERENCES
1. K. Lange, "3rd Offset Strategy 101: What It Is, What the Tech Focuses Are," (DoD Live, Mar 2016), http://www.dodlive.mil/index.php/2016/03/3rd-offset-strategy-101-what-it-is-what-the-tech-focuses-are/.

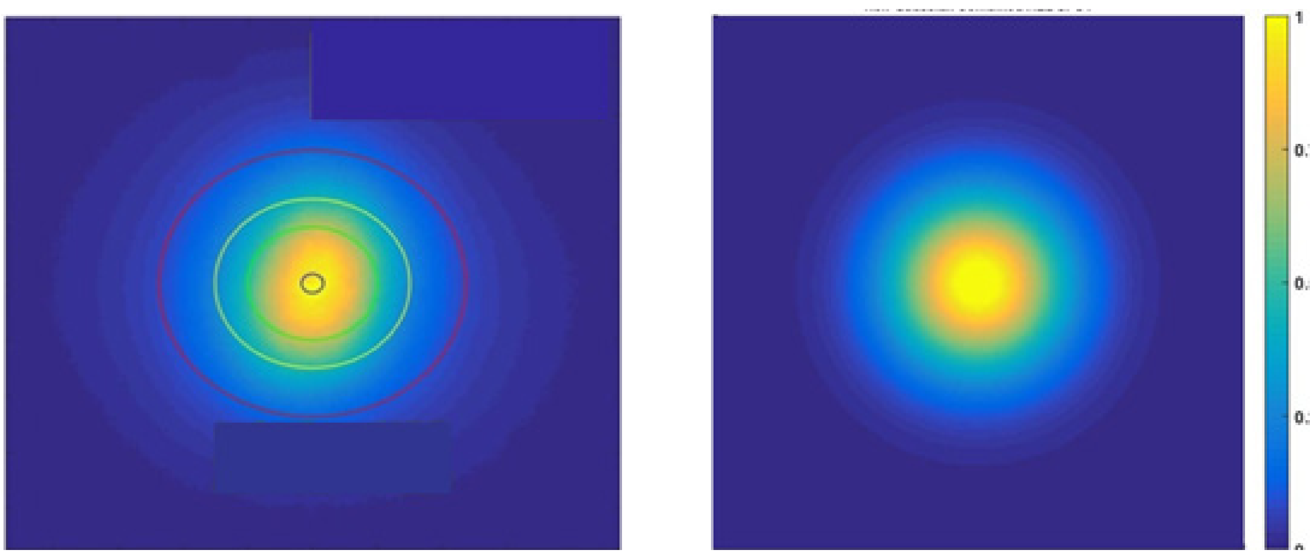

Figure 1. Comparison of ground test measured spot intensity at target (left) and HELEEOS output (right); prevailing wind was blowing cross-wise through the beam (400 off beam propagation path)

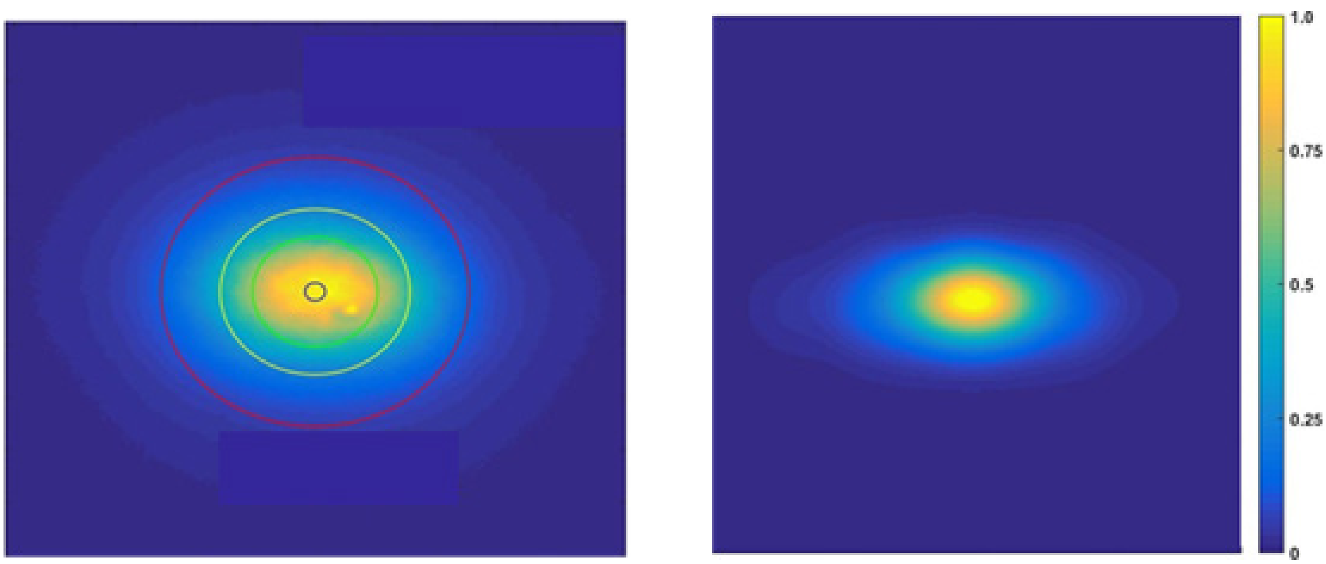

Figure 2. Comparison of ground test measured spot intensity at target (left) and HELEEOS output (right); prevailing wind was blowing along the beam propagation path.

CENTER SPOTLIGHT:
Center for Space Research & Assurance

Center for Space Research & Assurance Welcomes Col Dane Fuller

Ms. Shannon Tighe, Col Dane Fuller Dane.Fuller@afit.edu 937-255-3636 x4679

Figure 1: Col Dane Fuller

The Center for Space Research and Assurance (CSRA) is happy to welcome an Air Force Institute of Technology (AFIT) Alumnus, Colonel Dane Fuller, as their new Director. Col Fuller graduated with a Master of Science in Electrical Engineering (1999) and a Doctorate of Philosophy in Electrical Engineering (2011). Prior to returning to AFIT, Col Fuller served as a Senior Intelligence Officer within the Space Situatuinal Awareness Division.

In speaking with Col Fuller, he expressed how honored he is to return to AFIT as the CSRA Director and is looking forward to supporting the center's mission: to "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".

Stepping into the role of Director, Col Fuller has been supported by Drs. Richard Cobb and Eric Swenson, CSRA's Associate Directors. "Dr. Cobb and Dr. Swenson have been irreplaceable. When I arrived and saw their capability, my focus became to support them so that they may continue to excel."

Figure 2: Maj O'Hara standing with the new 3D Metal Printer

Col Fuller further expressed his desire to see the center continue to grow. As Director, one of his goals for the CSRA, is to see the center produce one flight per year with CubeSats. This year, the center is

Figure 3: The CSRA Team

excited to have their first bus, the "Gus Grissom" (named in honor of 1956 AFIT Alumnus Capt Virgil "Gus" Grissom) heading to space.

In addition to the CubeSat focus, the CSRA is proud to welcome the Air Force's third 3D Metal Printer. Col Fuller called the procurement of the 3D printer a "major accomplishment for CSRA". Though the printer has only just arrived at AFIT, it has already led to multi-funded research efforts and more are expected. Col Fuller and his team are excited by the possibilities the printer has brought to the center and are looking forward to diving into the research.

Col Fuller was quick to invite potential students and those interested in sponsoring research projects through the CSRA to come tour the center. Col Fuller expressed the uniqueness in partnering with CSRA, stating "What we do is government owned and government shared. If we can meet your needs on our (academic) timeline, then we can have a refreshing partnership."

To schedule a tour or to discuss research opportunities, please contact:
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AFIT Contributes to Development of Low-Cost Space Systems

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The military advantage of space-based communication, imaging, and navigation was demonstrated in OPERATION DESERT STORM, where U.S.-led coalition ground forces, aided by air and space forces, destroyed half of the Iraqi Army and liberated Kuwait in only four days. Since that time, the enormous impact of space forces in modern warfare has made space superiority an imperative for national security and defense of the U.S. and our allies. This creates a natural desire to increase the capacity and reliability of our space forces; however, space systems are generally expensive to procure and operate, driving military leaders to constantly seek new ways to lower the cost of space systems and to develop a professional space cadre within the Department of Defense to lead space system development and operation.

CubeSats offer a convenient entry point for teaching space system design and development within educational timelines and budgets. In this way, CubeSats enable AFIT to better educate the professional space cadre. CubeSats also hold promise for a low-cost solution to space systems because they are lightweight and typically have much shorter development cycles than larger spacecraft. CubeSats are classified as nanosatellites where one cube or 1U has the dimensions 10 x 10 x 10 centimeters. A 6U CubeSat consists of six 1U cubes and typically has a mass of around 14 kilograms. Lightweight spacecraft enable sharing of launch costs, which are a significant portion of the overall cost of space systems. In addition, CubeSat development cycles are often one to two years long, while larger traditional satellites generally take three to ten years to develop. Short development cycles cap salary costs and allow developers to integrate the newest, most cost-effective commercial technologies into their designs. However, true low-cost to space will only occur when commercial interests are driving production of CubeSats in large numbers.

For these reasons, AFIT has chosen to partner with industry to help lower the cost of spacecraft. For example, in 2016, AFIT's Center for Space Research and Assurance entered into a Cooperative Research and Development Agreement with Pumpkin, Inc., a CubeSat developer near Silicon Valley, California. The primary cooperative development activity was environmental testing of a 6U CubeSat bus called SUPERNOVA sponsored by the U.S. Navy Space and Naval Warfare Systems Command. Environmental testing demonstrates a satellite can survive launch and operate in the extreme environment of space.

The activity has two primary benefits for the Air Force. First, it directly supports Air Force student education and research by providing opportunities to participate in development of new space technologies alongside industry experts. This significantly benefits our faculty, staff and students, who annually design, build, integrate, and test CubeSats to perform high-priority sponsored DoD space missions. Furthermore, industry engagement has helped AFIT faculty and staff learn techniques to cut CubeSat development timelines in half. Second, it strengthens the U.S. industrial base of commercial nanosat providers. For instance, AFIT's participation enables Pumpkin, Inc. to reduce the price tag of its 6U bus by reducing some non-recurring engineering development costs. This is significant because the commercial market for CubeSats is incentivized by low-cost systems.

In conclusion, continued growth of commercial space markets is essential to achieve low-cost space systems, and low-cost space systems are essential to national security and defense. AFIT's Center for Space Research and Assurance thanks its supporters and sponsors for the opportunity to contribute to the development of low-cost space systems and the professional space cadre within the DoD.

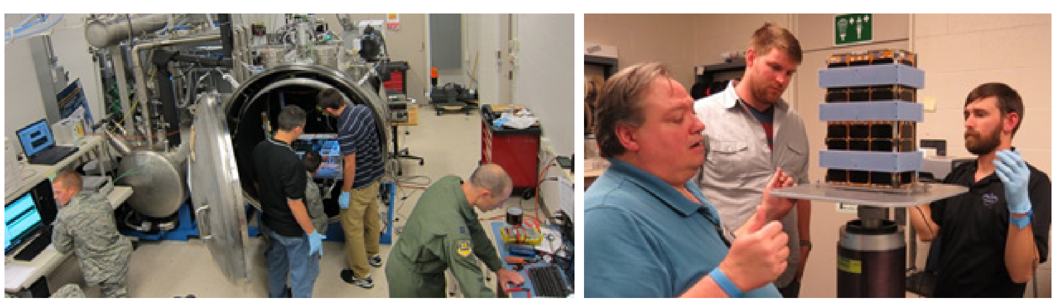

Figure 1. AFIT students and staff prepare a CubeSat for environmental testing (left) and Mr. Jesse Coffee (Pumpkin Inc.) observes AFIT research assistants Mr. Phil Smith and Mr. Chris Sheffield measuring the mass properties of a SUPERNOVA spacecraft (right).

Hyperspectral Imaging for Scramjet Combustion Diagnostics

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Ignition and maintenance of combustion in a high-speed environment represent technological milestones for scramjet-based hypersonic vehicles. The development of fuel injection techniques operable in ignition and continuous operation poses a difficult engineering problem; e.g. injection schemes tailored for continuous operation can make ignition unreliable. The ability to experimentally characterize and predictively model the injection and distribution of hydrocarbon fuels within the scramjet cavity is required to guide the development of technologies addressing these operational scenarios. However, high-speed flows present challenges for various established optical diagnostics, and are also difficult to model accurately. As a result, scramjet engine development has primarily relied on large, expensive tests rooted in design of experiment (DOX) principles and studied via *in situ* probes, which offer poor spatial and temporal resolution, and broadband imaging methods which offer qualitative information. The presence of nonlinear relationships and strong coupling between underlying physical variables complicates the interpretation of DOX results. Moreover, low-fidelity, *in situ* measurements disrupt the flow and permit only limited phenomenological insight regarding the factors governing high-speed flows.

With support from AFOSR, students and postdocs in both the Engineering Physics and Aeronautics and Astronautics Departments are working together with scientists and engineers at AFRL's Aerospace Systems Directorate, High Speed Propulsion Division to apply new optical diagnostics and computational methods to quantitatively understand fuel injection in scramjet combustors. Specifically, mid-IR (3–5μm) hyperspectral imaging has been (and will continue to be) used to investigate fuel injection, dispersion, mixing, and ignition in the cavity of a scramjet combustor. These measurements will be complemented by numerical simulations of the flow using AFRL's high-performance computing resources. Preliminary hyperspectral measurements of cold methane (CH_4) gas injected into a high-speed (Mach 2.2) vitiated airflow produced the first spatially-resolved maps of CH_4 concentration in a scramjet combustor, an example of which is presented in Figure 1. Additionally, information about CH_4 residency time in the cavity is captured by spectral measurement. Cold CH_4 in the core flow absorbs background radiation, while CH_4 entrained in the scramjet cavity has time to come to equilibrium with the high-temperature vitiated air, thereby emitting radiation above the background level. The absorption and emission characteristics seen in the inset spectrum were used to color the spatial map of CH_4. These quantitative measurements will be used to validate and improve numerical simulations being developed to describe scramjet fuel injection.

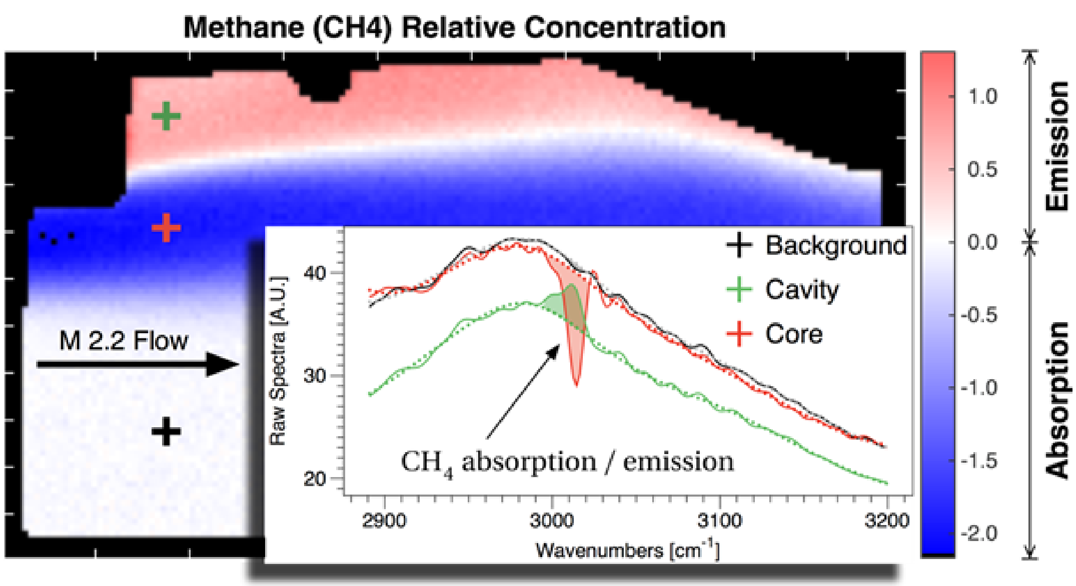

Figure 1. Spatial map of methane (CH_4) fuel injected into a vitiated airstream inside a scramjet combustor. The inset spectrum for the three pixel locations show the CH_4 absorption and emission features used to make the spatial concentration map.

Next-Generation Radar Imaging

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The Air Force Institute of Technology's Radar Instrumentation Laboratory (RAIL), led by Dr. Julie Jackson, develops advanced radar signal processing techniques for improved location, identification, and visualization of targets. Dr. Jackson and her team balance high fidelity modeling and computational efficiency through feature-based and statistical models that provide insight into scattering physics. They extract relevant features during image formation and provide enhanced image visualizations. Dr. Jackson works closely with the Air Force Research Laboratory Sensors Directorate to develop these tools in support of both human radar analysts and automatic target recognition algorithms.

High fidelity electromagnetic scattering predictions for targets and backgrounds are desirable but computationally inefficient. Traditional radar signal models are fast but inaccurate. Dr. Jackson and her students characterize signal propagation from source to receiver and develop techniques to efficiently predict and extract relevant radar signatures. Target signals are broken into canonical objects, streamlining both signature prediction/validation and automatic target recognition processes through compact, salient feature representations. Background clutter is characterized using statistical estimation techniques. Recent work characterizes multiple background types from coarse resolution measurements, allowing for faster data collection and improved target detection and performance prediction. (See Figure 1.)

Leveraging canonical scattering models and advanced signal processing techniques, enhanced image visualizations are generated. Multiple measurement channels are decoupled, removing spurious targets, and extracting polarization scattering features during image formation. Extension to 3D produces radar visualizations not typically achievable from realistic, data-limited remote sensing (see Figure 2).

The RAIL team is at the forefront of radar scattering phenomenology and signal processing research. Future work will continue to develop next-generation radar products in support of the warfighter.

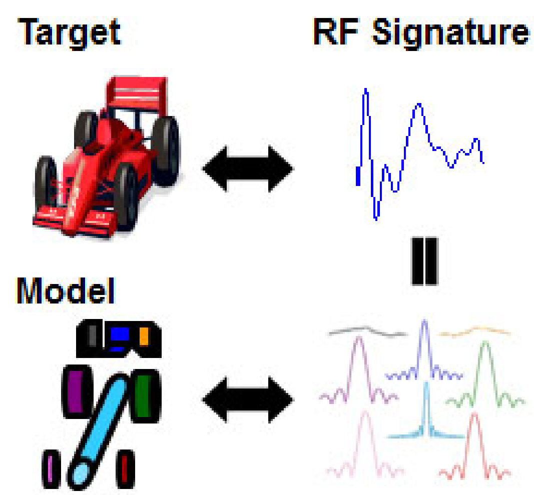

Figure 1: Canonical scattering models balance the need for accurate electromagnetic prediction with the need for tractable signal processing schemes.

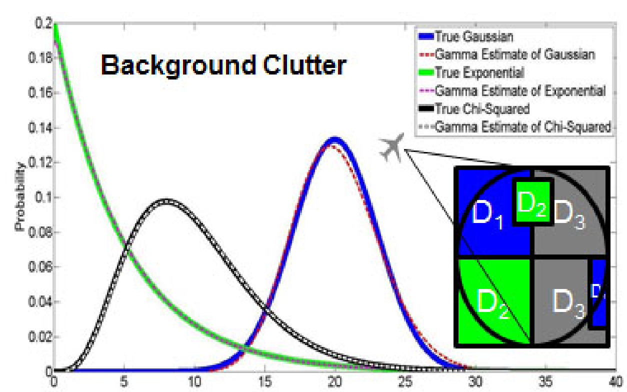

Figure 2: Statistical estimation techniques discern scattering responses from multiple terrain types for improved target detection and performance prediction schemes.

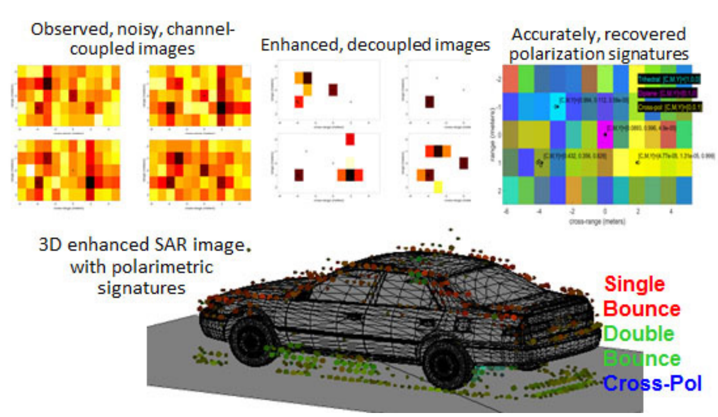

Figure 3: Polarimetric signatures and sparsity-enhanced images aid target visualization and recognition in traditional 2D radar images and novel 3D images.

AFIT Sensor and Scene Emulator for Testing (ASSET)

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The AFIT Center for Technical Intelligence Studies & Research (CTISR) has developed a physics-based model to generate synthetic wide area motion imagery (WAMI) data sets.

ASSET was developed to meet the need for applications where precise knowledge of the underlying truth is required but is impractical to obtain. For example, due to accelerating advances in imaging technology, the volume of data available from WAMI sensors has drastically increased over the past several decades, and as a result, there is a need for fast, robust, automatic detection and tracking algorithms. Evaluation of these algorithms is difficult for targets that traverse a wide area (100-10,000 km) because obtaining accurate truth for the full target trajectory often requires costly instrumentation. Additionally, tracking and detection algorithms perform differently depending on factors such as the target kinematics, environment, and sensor configuration. A variety of truth data sets spanning these parameters are needed for thorough testing, which is often cost prohibitive. The use of synthetic data sets for algorithm development allows for full control of scene parameters with complete knowledge of truth.

For analysis using synthetic data to be meaningful, however, the data must be truly representative of real sensor collections. The synthetic data has realistic radiometric properties, noise characteristics, and sensor artifacts including jitter and rotation. For these simulations, background scenery is based upon available satellite imagery (e.g. LANDSAT), and multiple cloud layers with independent motion can be added based on fractal models that warp as they move.

If you are interested in learning more about, gaining access to, or collaborating with us on ASSET's development, please contact Dr. Bryan Steward, bryan.steward@afit.edu, 937-255-3636 x4639.

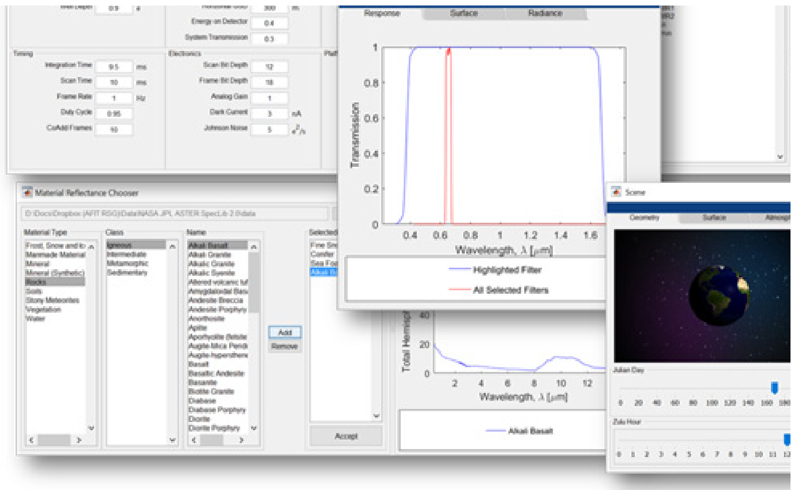

Figure 1: Graphical user interface (GUI) used to specify sensor configuration, spectral response, solar geometry, surface material reflectance properties, and atmospheric characteristics.

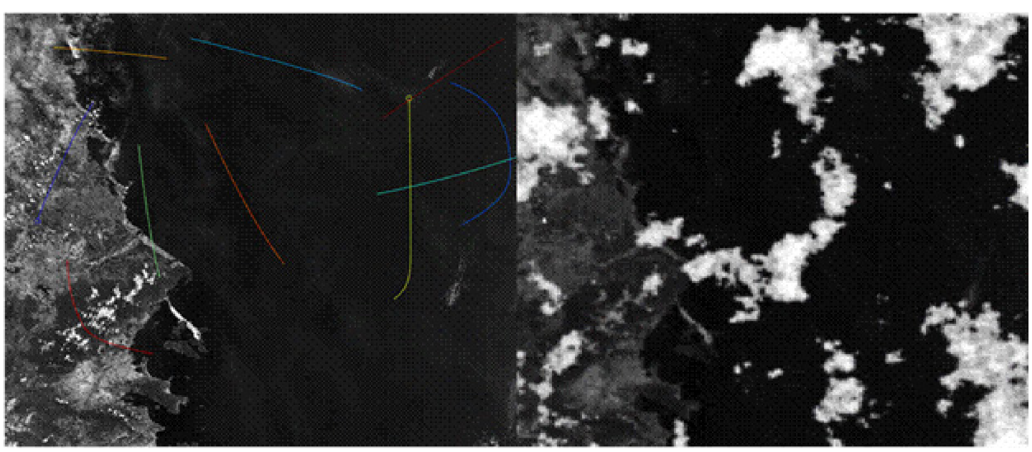

Figure 2: Left: sample imagery, showing the initial commercial satellite imagery along with colored tracks indicating where moving targets will be added. Right: finished simulated data with realistic properties, clouds, and embedded targets.

Mitigating Cyber Attack on Vehicles

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Figure 1: Modern Car Connectivity (aecouncil.com)

Modern automobiles are equipped with many sensors, actuators, and controls to improve the performance and life-safety aspects of those vehicles. As the number of sensors and actuators in aircraft and automobiles increases, the complexity of the wiring needed to interface them to the associated controllers and microprocessors at the heart of the control systems necessarily increases. Data communication busses, such as the Controller Area Network (CAN), and related architectures have been designed to reduce the amount of wiring in these ever more complex control systems. CAN is now found in most automobile systems, and was mandated by the United States government to be included on all vehicles beginning in 2008. Despite the maturity and ubiquity of CAN and other bus architectures, security is not yet prevalent as a consideration in the design and implementation of the standard.

Recently, there have been several successful automobile exploits conducted by security researchers who were able to take nearly full control of a vehicle via any single connection to the CAN bus. Capt Eddie Caberto in the Department of Electrical and Computer Engineering and the Center for Cyberspace Research has developed a CAN test-bed in an effort to understand the architecture and to develop systemic protection mechanisms, as well as to pivot lessons learned toward other bus architectures, notably MIL-STD-1553, which is the standard communication bus for military aircraft.

As part of the new CAN testbed, Capt Caberto constructed an example architecture which separates safety critical functioning from the more vulnerable components on the CAN bus. During simulated cyber attacks, this architecture was able to disconnect the safety critical components from the source of the attack, demonstrating resiliency in the presence of cyber attack.

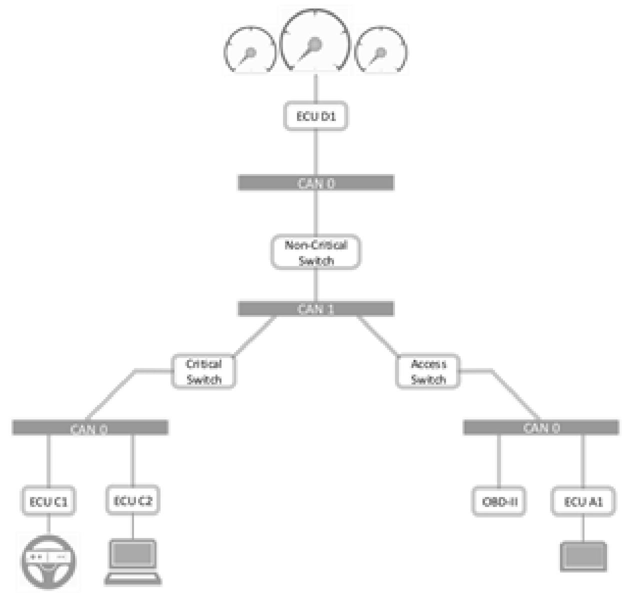

Figure2: Secure CAN Architecture

For information on attending AFIT and the Center for Cyber Research, or to sponsor a research project, please contact:

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Smartphone Sensors Used for Non-GPS Navigation

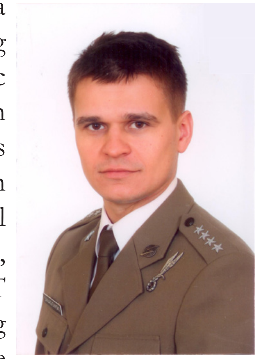
Ms. Amy Rollins, Skywrighter Staff Original Publication 19 August 2016

Capt. Piotr Smagowski, a Polish officer who took part in the Engineer and Scientist Exchange Program (ESEP) at the Air Force Institute of Technology's Autonomy and Navigation Technology Center at Wright-Patterson Air Force Base, knows a thing or two about smartphones – such as how to know where you are without using GPS. His work ultimately may help warfighters with their navigation needs.

Smagowski was hosted from October 2015 to June 2016 through ESEP, a Department of Defense program promoting international cooperation in military research and development through the exchange of defense scientists and engineers. His work at the ANT Center, which seeks to identify and solve challenging navigation and autonomous and cooperative control problems, demonstrated a new non-GPS navigation capability using only smartphone sensors. His project fit well with the ANT Center's goal of developing navigation technology that ensures people can navigate anywhere, anytime, using anything.

Capt. Piotr Smagowski is a Polish officer who took part in the Engineer and Scientist Exchange Program (ESEP) at the Air Force Institute of Technology's Autonomy and Navigation Technology Center at Wright-Patterson Air Force Base. His work at the ANT Center, which seeks to identify and solve challenging navigation and autonomous and cooperative control problems, demonstrated a new non-GPS navigation capability using only smartphone sensors (Contributed photos)

Smagowski's work led to a paper, "Smartphone Navigation Using Barometric Altitude and Topographic Maps." The paper is currently in review for the Institute of Navigation's annual GNSS+ (Global Navigation Satellite System) international conference in Portland, Oregon, Sept. 12-16. Additionally, the ANT Center has already received funding from the Army related to the ESEP-developed algorithm, and other funding opportunities exist with AFRL's rapid development center.



Capt. Piotr Smagowski from Poland participated in AFIT exchange program.

"We were able to develop the algorithms and Capt. Smagowski was able to implement them," said Dr. John Raquet, AFIT professor and ANT Center director.

He served as Smagowski's advisor and developed the idea for the project, which the captain executed. The capability is only available for demonstration currently. Raquet explained that smartphones are readily available and contain software for counting steps and a magnetometer for determining the direction one is heading. With those, one can develop a sense of where he or she is going as one walks along.

"But over time, that has errors and will not give you a very good trajectory. It's very rough," Raquet said. "To correct it, we added a third piece of information – this is the novel part – which uses the smartphone's barometric altimeter. That's a sensor that can tell altitude based on pressure, and it's the same basic thing that planes use."

With that measurement and comparison to an altitude map of the area being traversed, Smagowski developed an algorithm that was able to correct the trajectory and determine exact location.

"We chose multiple testing areas which had different kinds of difficulties and features," Smagowski said. "Those helped the algorithm to work."

Charleston Falls Preserve in Miami County and greenspace near AFIT's location in Area B served as test areas. Smagowski led ANT Center interns on a number of hiking expeditions to test the capability, Raquet said.

"At a technical level, I think it's been very successful," Raquet said. "I think Piotr did a fantastic job in solving a lot of very practical problems to make the system work. He answered the big question of whether the capability could be developed. Because of his work, we were able to add a new approach to the ANT Center's research. We want to continue to develop the concept and build on Piotr's work."

The captain said he was interested in the many layers and aspects of the project, which ranged from mathematics to software to the practical. While he is pursuing a Ph.D. in signal processing in Poland, there is little relation to his ANT Center project.

Smagowski said his participation in the exchange program benefited his language skills and helped him develop an idea of how the center's and AFIT's work is organized. He is filing a report with his superiors soon and looks forward to sharing his experiences with many others in the Polish armed forces, he said.

"I would like to emphasize that the non-GPS navigation is very, very important, so this contribution is something I would like to give to the Polish armed forces, including the technology and important details," Smagowski said. "I'm glad I was able to be a part of the ANT Center and receive technical knowledge from Dr. Raquet and the other colleagues."

Smagowski's presence had a personal as well as a professional side, Raquet said.

"All of us enjoyed getting to know Piotr and learning about Poland. We also enjoyed meeting his wife and new baby son as well," Raquet said.

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AFIT Supports DoD-Wide Test and Evaluation Improvements

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The Scientific Test and Analysis Techniques Center of Excellence (STAT COE) became operational in July of 2012 as a customer-focused initiative with the intent to provide direct Test & Evaluation (T&E) support to 20 Major Defense Acquisition Program managers and their Chief Developmental Testers. Over the last four years, the center has expanded to 39 programs through major acquisition program managers seeking support. Many smaller efforts ranging from test planning to reliability and data analysis were supported by assistance requested through the "Ask a STAT Question" section of the Center's website. The STAT Experts work directly with the larger integrated test teams to assist by injecting more statistical rigor into defensible test planning, design, execution, and assessment processes.

In addition to direct program support, over the last year the STAT COE developed 9 best practices, case studies, and journal articles, in addition to a one-day STAT course for leadership at the Air Force's Arnold Engineering Development Center (AEDC). The best practices (available at www.AFIT.ed/STAT) enable the acquisition community to add rigor to its tests and follow a defendable, traceable process that is consistent with the scientific method. The Department of Defense (DoD) acquisition community is reaching to AFIT to answer its difficult STAT questions. The STAT COE is baseline funded by the OSD DASD (DT&E) with an annual budget (FY 2016) of $1.7 million in addition to research and education initiatives accredited to more than $1.8 million in FY 2016.

These initiatives include STAT for Cyber Resiliency of Weapons Systems course development, sponsored by HQ AFMC/A3F, providing research and program support to the Navy T&E division (N842B) in the form of STAT for automatic test and analysis of automated software testing (AST), and T&E of the JSF Joint Simulation Environment (JSE) verification and validation (V&V) data development in support of the Battlespace Modeling V&V Office at NAVAIR. The STAT COE is closely linked to the Office of the Secretary of Defense (OSD) and is an integral part of empowering program leadership to plan and execute more efficient and effective tests resulting in decision quality information for Better Buying Power.

For more information on attending AFIT and the STAT COE Center, or to sponsor a research project, please contact:

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Bringing a Rapid Prototyping Approach into the Classroom

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The traditional "chalk and talk" lecture model for engineering education is predominant in most engineering classrooms, despite the fact that it has been proven to be ineffective at engaging students. The Office of Naval Research is sponsoring a partnership between AFIT and Western Washington University (WWU) to develop a makerspace-like model for delivery of course content. Makerspaces are small, localized grassroots organizations of hobbyists devoted to development and exploration of technology. In the context of defense education, the maker movement mirrors the approach of rapid prototyping and rapid response used to combat emerging threats.

The model in development by AFIT and WWU features "tinkering" activities and "gamification." Every two weeks, the students will be given a new project based on real-world applications, hardware, and a set of goals. Examples include camera alignment, microphone-based speaker position tracking, spectrum monitoring, and radio direction finding. Students are tasked to explore the hardware, develop a baseline response by using course principles, and compete to address challenge problems as much as time allows. About half of the development will occur during the contact hours, made possible by pre-recording the lectures for the students to view in advance, per a "flipped classroom" model. The tinkering approach gives students practice with problem solving, and the competitions provide intrinsic motivation. The figure below shows an example from the initial activity in AFIT's Introduction to Signal Processing course.

The activities developed by AFIT and WWU will be hosted on a WWU website along with pedagogical tips and solutions for instructors. Due to the support from ONR, AFIT will be specifically reaching out to the Naval Academy and the Naval Postgraduate School to encourage a wider adoption of this approach among naval educational institutions.

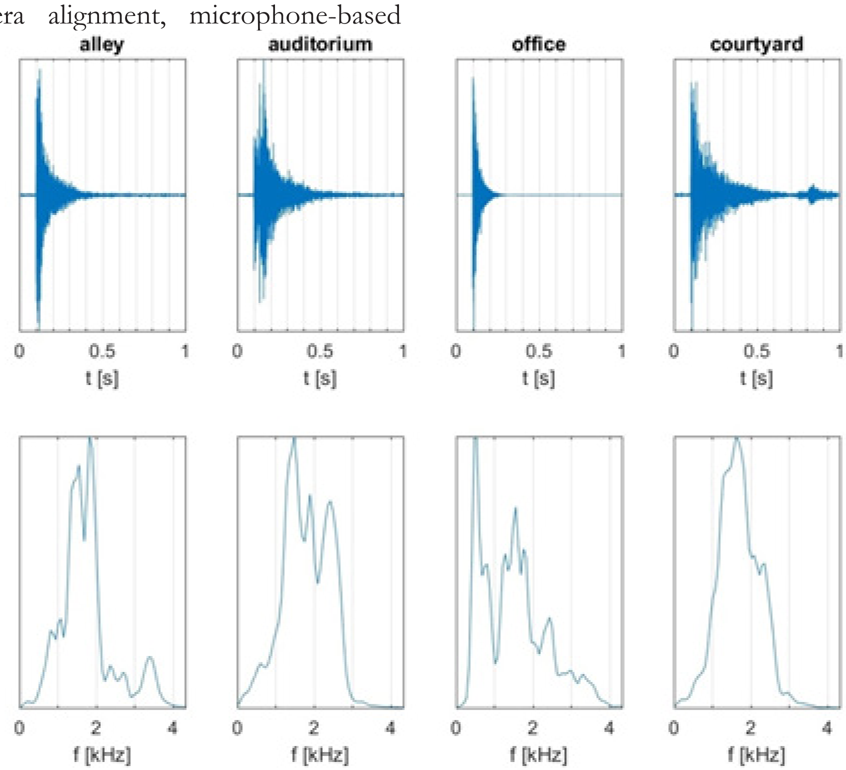


Figure 1: Four sample acoustic impulse responses (top) and their frequency-domain representations (bottom) gathered by AFIT students. This activity was designed to familiarize students with an audio transmitter and receiver in lieu of functionally similar to, but much more expensive radio transceivers. The class competed to find responses with the longest responses, provided the students could explain the length in terms of the physical geometry of the collection area.

Center for Operational Analysis Aiming for the Future

Dr. Paul Hartman Paul.Hartman@afit.edu 937-255-3636 x4521

The Center for Operational Analysis (COA) achieved immense success in Fiscal Year 2016 through implementation and execution of the Center's service strategy, 'Outreach, Engagement, and Collaboration'. The Center Director, Dr. Paul L. Hartman, attributes much of the Center's success to the vision outlined by Air University Commander and President, Lieutenant General Steven L. Kwast in the September 2015 Air University Strategic Plan:

"We must reach more Airmen and, as we do so, ensure that the developmental experiences that we provide are rich, relevant, and tailored to help bring our Airmen and our Air Force to maximum effectiveness. We must also lean forward to analyze and address the challenges facing our Airmen and our leaders, providing well-researched, thoughtful recommendations that directly support the defense of our nation and its freedoms that are at the heart of our calling to serve. We must be focused on outcomes, ensuring that we are constantly analyzing, assessing, and improving all that we do to be more relevant to Air Force and stakeholder needs even as we continue to become more effective and efficient.In short, we will rethink conflict, reimagine airpower, and build agile leaders." (Commander's Intent, pg 2)

Dr. Hartman committed to operationalizing the Air University (AU) Commander's Intent when he accepted his 3-year appointment as the COA Director on 13 October 2015. When asked about his appointment, Dr. Hartman said, "It is an honor to have been selected for this appointment. When I graduated from AFIT in 1997 (M.S., Logistics) I never imagined that I would graduate from AFIT again 16 years later as the first graduate of the Department of Operational Sciences' new Ph.D., Logistics, program. To be afforded the opportunity to return to AFIT a third time in my 24-yr public service career in this new role as Director of the Center for Operational Analysis is extraordinary. I very much appreciate the trust and confidence Drs. Pignatiello, Ries, Badiru, and Stewart demonstrated in selecting me to re-architect the COA's role in supporting USAF Senior Leader objectives."

Dr. Jeffery Weir, COA Director of Reasearch

Dr. Paul Hartman, Director of COA

Dr. Hartman is quick to share credit for the COA's FY16 success with the COA Director of Research, Dr. Jeffery Weir. Together—"one team, one fight" as Dr. Hartman would say—he and Dr. Weir objectively, and with great intention, developed the COA's first multi-year Strategic Plan, expanded the structure of the Distinguished Review Board (DRB), and established 7 core vertical mission sets as the framework of the FY16 'Outreach, Engagement, and Collaboration' service strategy. Under the leadership of Drs. Hartman and Weir, this multi-pronged approach helped the COA capture over $4.2M in FY16 new sponsoring-agency research, nearly one-sixth of the total $25M in FY16 sponsoring-agency funding that flowed through the AFIT Office of Research and Sponsored Programs.

Drs. Hartman and Weir could have architected the COA any number of ways, but to them it was important to have the COA linked to the Air University strategic vision. "At AFIT, we are the customer-facing agents for AU, and it is critically important that the COA's outreach, engagement, and collaboration activities serve to promote AU and AFIT as value-adding contributors to the USAF mission. Goals 2.2, 2.3, and 3.2 anchor the COA's service strategy and serve to ensure USAF Senior Leaders understand that the COA's research objectives are inextricably linked to and supported by AU and AFIT."

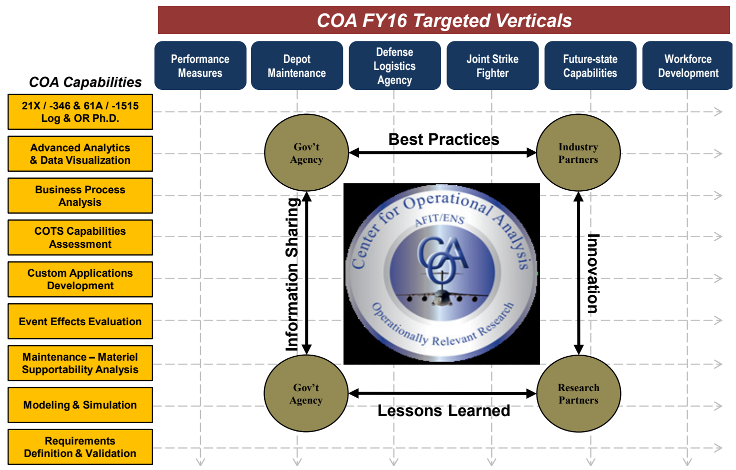
Expanding the COA Distinguished Review Board

The Department of Operational Sciences provides Master's and Doctoral degrees in Logistics and Supply

Chain Management, Logistics, and Operations Research. As the department coin illustrates, the degrees are two sides of the same coin, each serving to support the education and research objectives of two different USAF Flag-level officials from different vertical domains within the USAF core functional structure: 1) the Deputy Chief of Staff for Logistics, Engineering and Force Protection (HAF/A4), and 2) the Director for Studies, Analyses and Assessments (HAF/A9). Viewing previous Distinguished Review Boards (DRBs) through the lens of AU Goals 2.2, 2.3., and 3.2, Drs. Hartman and Weir identified the underrepresentation of senior military and civilian officials from USAF operational commands as a significant limitation in the COA's ability to engage in "…challenges of today and tomorrow" explaining, "the COA DRB needs senior officials from both the logistics and ops research front-line operational communities if the COA is to be a relevant force multiplier in the future." With that perspective as a driving force, Dr. Hartman expanded the COA's March 2016 DRB to now include senior military and/or civilian officials from multiple agencies and organizations.

The expansion of the COA's DRB provided Drs. Hartman and Weir with much needed insight into the core challenges USAF and DoD Senior Leaders face in today's changing environment. Drs. Hartman and Weir used this insight to establish the COA's FY16 Targeted Verticals—the solution-based framework between AFIT/Academia, Industry, and Government, intentionally matched with the innovative capabilities of the COA, to provide real solutions to today's top operational challenges. Drs. Hartman and Weir continue their on-going outreach and engagement strategy with DoD Senior Leaders to identify the specific operational challenges where the COA can apply rigorous quantitative and qualitative tools, methodologies and approaches to analyze and solve complex operations and supply chain problems.

In explaining the graphic, Dr. Hartman tells senior officials that while the COA is uniquely positioned to apply a wide variety of tools and techniques to solve complex problems in near real-time, it is the graphic in the middle of the diagram which addresses how the COA has been able to consistently add value to sponsoring agencies—the ability of the COA to act as an independent, objective, and academically-grounded entity standing between Government Agencies, as well as Industry and Research Partners, to deliver collaboratively-developed, sustainable solutions for the COA's sponsoring agencies. Of course, as Dr. Hartman points out to sponsoring agencies, none of this would be possible without



the direct involvement and support of the AFIT Leadership Team, distinguished faculty, and staff members of AFIT. "We are all in this together," says Dr. Hartman, "we've been given the responsibility of being exceptionally good stewards of the USAF, AU, and AFIT brand…each was here long before we arrived and, with our personal commitment to excellence, each will be long after we've moved on."

In keeping with this commitment to excellence, Drs. Hartman and Weir have built a solid foundation for the COA moving into FY17. Critical to this FY17 foundation are the COA's military and contractor civilian staff members who are, "…doing the heavy lifting that keeps this place moving forward" says Dr. Hartman, "they are the glue that holds the foundation together!" Both Drs. Hartman and Weir expressed a sincere debt of gratitude to the COA Team and look forward to all they will achieve in FY17.

The COA Team

RESEARCH HIGHLIGHTS

Suitability Analysis of Continuous-Use Reliability Growth Projection Models

Dr. Darryl Ahner, Capt Benjamin Mayo   Darryl.Ahner@afit.edu   937-255-3636 x4708

Capt Benjamin Mayo, advised by Dr. Darryl Ahner, Department of Operational Sciences, and Major Jason Freels, PhD, Department of Systems Engineering and Management of the OSD Scientific Test and Analysis Techniques Center of Excellence, won the prestigious Barchi Prize at the 84th Military Operations Research Society Symposium for his paper "Suitability Analysis of Continuous-Use Reliability Growth Projection" awarded to the best paper given at the previous MORS Symposium. Between 2006 and 2011, Director Operational Test & Evaluation (DOT&E) noted 26 of 52 Department of Defense acquisition programs failed to meet reliability thresholds, but were approved, leading to degraded operational performance, increased operational and maintenance (O&M) costs, and increased safety risks for personnel involved. Reliability plays a key role in the O&M cost of a system. If reliability is overestimated during development, the system may become overburdened with unscheduled maintenance and excess repair costs in the field. Unfortunately, it is difficult to estimate a system's ultimate reliability during the early stages of development. Reliability growth can be defined as the positive improvement in a reliability parameter over a period of time by implementing a corrective action to system design, O&M procedures, or the associated manufacturing process.

Reliability growth planning models are used to construct a reliability growth planning curve, Figure 1, which serves to set periodic goals and a benchmark to which the system managers can be held accountable. Assessing the system's actual reliability growth is done with reliability tracking models. The primary focus of this study is a comparison of reliability growth projection models designed for continuous use, repairable hardware systems. These types of models are used to project everything from the battery life of cell phones to the mission capability of next generation aircraft. Determining the potential future reliability for a system at the beginning and throughout development and managing reliability growth effectively can have significant impacts to the planning and programing decisions and costs. This study lends insight to the appropriate use of the various reliability growth models for differing systems.

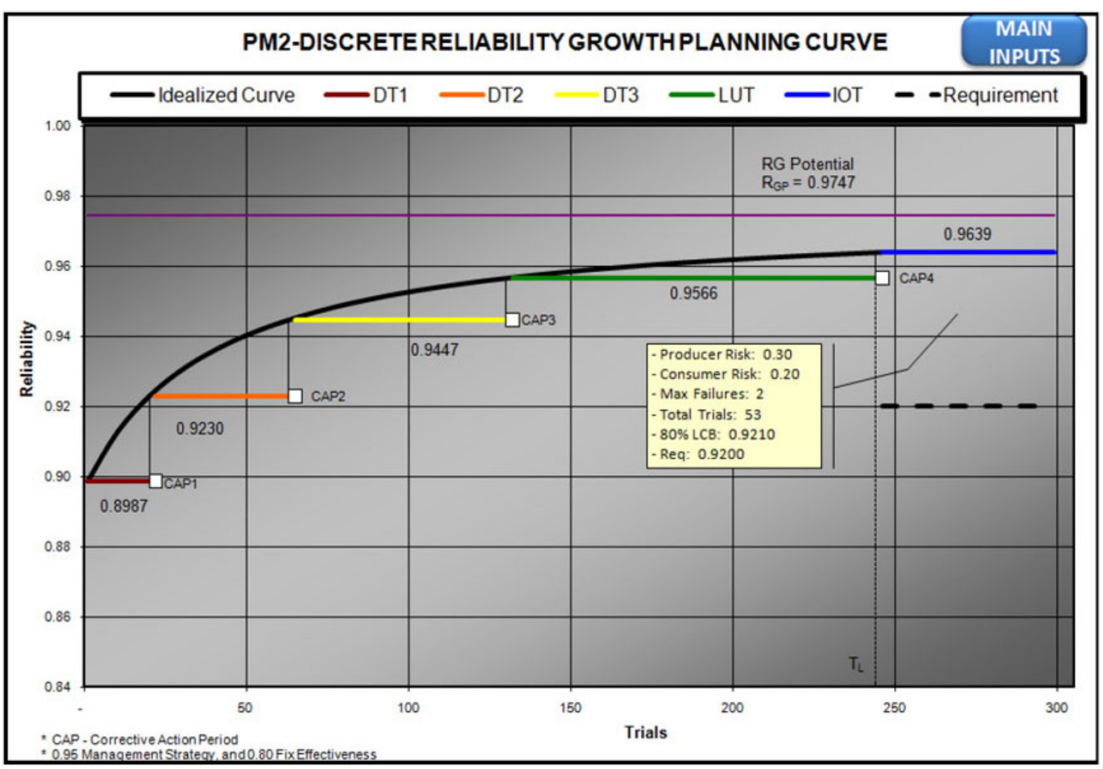


Figure 1: Taken from: D. A. U. (DAU), "Test & Evaluation Management Guide Chapter 17 - Logistics Support T&E," 26 August 2016. [Online]. Available: https://acc.dau.mil/CommunityBrowser.aspx?id=518310. [Accessed 14 October 2016].

AFIT Technical Writers Support Scientific Advisory Board

Lt Col James Fee James.Fee@afit.edu 937-255-3636 x4438

The Secretary of the Air Force (SecAF) directed the Scientific Advisory Board (SAB) to conduct studies in 2016 in the following areas: Data Analytics to Support Operational Decision Making, Responding to Uncertain or Adaptive Threats in Electronic Warfare, Airspace Surveillance to Support A2/AD Operations, and a Quick Look on Directed Energy Maturity for Airborne Applications. The SAB requested AFIT faculty support to provide technical writers for these studies. These technical writers were requested to do the following: act as technical sounding board during study panel caucus, advise panel on USAF practices, lingo, and operational relevance; populate reference library for panel by collecting briefings received, conducting literature searches and defining technical terms; prepare the final draft of the study briefing to present to the SecAF and CSAF; and draft, coordinate and correct the final study report. Lieutenant Colonel James Fee from AFIT/ENP was selected to serve as the technical writer for the study, "Directed Energy Maturity for Airborne Applications."

This study was requested by Lieutenant General Bradley A. Heithold, the commander of the Air Force Special Operations Command, to understand alternatives to integrate an offensive high energy laser solution on an AC-130W (See Figure 1.). USSOCOM desires the demonstration of an Operationally Relevant capability on an AC-130W in 2-3 years. Lt Col Fee's dedicated efforts guided a 10 member team of senior scientists, engineers, and retired three and four star general officers through a demanding agenda of travel and information gathering. His efforts aided in determining the technology maturity for several directed energy systems, identifying missions suited for airborne high energy lasers, and understanding effects against various classes of targets. The finding and recommendations of this study were classified in nature, but provided expert advice to the SECAF, CSAF, and AFSOC regarding viability of emerging technology and future scientific and technology investment for Air Force. This study report was presented for coordination 3 months ahead of schedule.

Figure 1: The AC-130 platform was studied as a candidate for an airborne laser system both as an offensive and defensive system. Photo source: http://nationalinterest.org/blog/the-buzz/americas-lethal-ac-130-gunship-steroids-16185.

Figure 2: The AC-130 in flight. Photo source: http://nationalinterest.org/blog/the-buzz/americas-lethal-ac-130-gunship-steroids-16185.

AFIT - AFRL's 1st Hypersonic Technologies Collaboration Planning Workshop (HTCPW)

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On July 19th-20th of 2016, AFIT and AFRL jointly hosted the first Hypersonic Technologies Collaboration Planning Workshop (HTCPW) to foster collaboration and cooperation amongst the disparate military and civilian government entities working in the hypersonics arena. The intent of the workshop was to review the current threat environment, discuss current research activities across government organizations, establish potential areas of collaboration, and discuss enhancement of graduate studies in hypersonics technology areas. Representatives from AFIT, AFRL, NASIC, NASA, OSD, USAFA, AFLCMC, NORAD, and AEDC presented material on various aspects of hypersonic technologies via 18 talks.

Figure 1: (Left to Right) Dr. S. Sritharan, Dr. G. Zacharias, Dr. H. Ries, Dr. T. Jackson.

The event was attended by the USAF Chief Scientist, Dr. Greg Zacharias, and more than 75 participants actively engaged in hypersonics. After introductory remarks by Dr. Tom Jackson, Senior Scientist for Hypersonics at AFRL, and Dr. Sritharan, Provost of AFIT, a current threat briefing on foreign hypersonic capabilities was provided by personnel from NASIC at the classified level to provide context to start the workshop. After an evaluation of the threats faced, discussions and presentations were made by the various groups represented at the workshop covering topics including threat detection, hypersonic propulsion research, computational research, diagnostic development, hypersonic facility development of test equipment, and technology maturation activities.

Figure 2: Panel Members participate in a discussion with HTCPW attendees.

On the final day, after several further presentations, the workshop concluded with a panel discussion highlighting the need for continued collaboration among the participating organizations, the inclusion of other organizations, and the need for a coherent strategy regarding the development of hypersonic weapons and the defense from such. The discussion was lively and participants appreciated the breadth of the material.

Presentation materials have been disseminated to the participants of the workshop, and notional plans for a similar future workshop to be held in 2018, were developed. Special note was made of the need for continued educational readjustments to address the decline in hypersonics experience in the community and several collaborative efforts between participants have already begun. The workshop was organized by a small joint team of AFRL/RQH and AFIT representatives.

For more information, please contact Dr. Robert Greendyke at robert.greendyke@afit.edu .

ACADEMIC HIGHLIGHTS

Reaccreditation of Engineering Programs by ABET

Dr. Paul Wolf Paul.Wolf@afit.edu 937-255-3636 x4560

Accreditation Board for Engineering and Technology (ABET) is the accreditation agency for academic programs in engineering, applied science, computing and engineering technology. The Graduate School has a longstanding relationship with ABET that dates to 1964 when the Nuclear and Astronautical Engineering programs were the first accredited. Today, the Graduate School has nine academic programs accredited by two of the four commissions of ABET.

The Engineering Accreditation Commission accredits the following programs: Aeronautical Engineering, Astronautical Engineering, Computer Engineering, Electrical Engineering, Engineering Management, Environmental Engineering and Science, Nuclear Engineering, and Systems Engineering. The Applied Science Accreditation Commission accredits the Industrial Hygiene program.

These nine academic programs were the subject of a six-year comprehensive reaccreditation review in AY 15 – 16. After reviewing detailed self-study reports with associated evidence, program evaluators spent three days at AFIT examining various aspects of the academic programs to ensure they met the criteria for accreditation established by ABET. The visit included substantiation of the evidence provided in the self-study report and interviews with faculty, students, administrators, support staff, and each program's various constituents. The visiting teams commended the Graduate School for its mission focus, the quality of the faculty and laboratory facilities, and its research connections to various national defense organizations that allows students and faculty to perform research in defense-applicable contexts. They also noted the "exceptionally homogenous sense of purpose" of the faculty and students which allows AFIT to "meet the unique needs of its constituents". The two Commissions were unanimous in their conclusions about the quality of these academic programs. Consequently, these programs received the maximum reaccreditation of six years from ABET. This result provides assurances to the public and the Air Force that these academic programs meet the quality standards established by the professions for which those programs prepare graduates.

UPCOMING EVENTS

Preparing for AFIT's 100th Celebration

Ms. Shannon Tighe

What started as a school for select officers in 1919, has grown into a premier educational institution for: officer and enlisted students, international students, Department of Defense civilians, and members of all branches of the armed services.

Here at AFIT, we continue to stress the values that we were founded on, excellence in education and research, to move AFIT through the twenty-first century, retaining its flexibility and resourcefulness in accomplishing its mission.

2019 will mark AFIT's 100th anniversary, and plans are underway for a celebration befitting such an occasion. If you would like more information about the plans, please contact the Alumni Affairs and Institutional Advancement Manager, Ms. Kathleen Scott, at kathleen.scott@afit.edu.

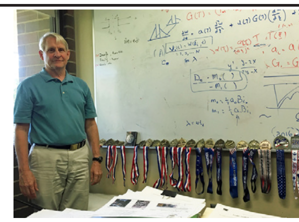
FACULTY AWARDS & ACHIEVEMENTS

2016 Air Force Science, Technology, Engineering & Mathematics (STEM) Awards

Congratulations to Dr. Raymond Hill and Dr. Willie Harper, for being selected as the 2016 winners in the Air Force Science, Technology, Engineering, and Mathematics (STEM) Awards program. This Air Force-level recognition of their excellence in teaching and basic research (respectively) is especially noteworthy, considering the high level of competition for these awards.

AFIT's Very Own "Star Runner" - Dr. William Baker

Dr. William Baker, an associate professor of mathematics, has participated in his 20th AF Marathon, making him one of WPAFB's 35 Star Runners. "I have been an avid runner for many years. Arriving at AFIT in 1987, I joined the Department of Mathematics and Statistics teaching a wide variety of courses in applied mathematics. Having run numerous marathons around the country, it was only natural to take on the Inaugural Air Force Marathon in 1997 and celebrate the USAF's 50th anniversary. Each year brings a new challenge. You must be properly trained and prepared for the variable weather conditions September in Ohio can bring. I enjoy this marathon not only because it is in my backyard, but our group of STAR runners encourage and support one another from start to finish. With 20 years behind us, age is beginning to take its toll, however, I hope to continue for years to come."



Dr. Baker with each of his AF Marathon Medals

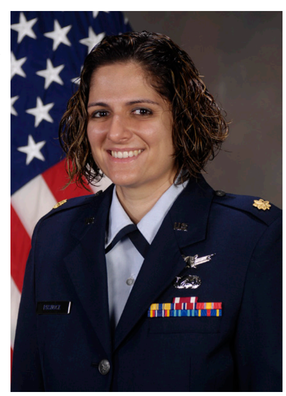
AETC Educator of the Year - Major Christina Rusnock

Ms. Katie Scott

Major Christina Rusnock, Assistant Professor of Systems Engineering was selected as the 2015 Air Education and Training Command's Officer Educator of the Year for her significant contributions to AETC's educational mission during the academic year. "It is a great honor to receive this award. Even though I am the one receiving this recognition, these accomplishments are actually shared accomplishment with my colleagues and students at AFIT. We are a team and our research contributions are a collective effort." stated Major Rusnock.

Major Rusnock was personally responsible for over $150K in research grants, one book, three peer-reviewed journal articles, 18 conference papers, and 19 academic posters including "Best Paper" and "Best Poster" awards. She has served as the thesis advisor for seven Systems Engineering Master's students. She is the Program Chair for the Systems Engineering Distance Learning (SE DL) Program, which includes two Master's programs and two graduate certificates and has been the SE DL Academic Advisor for over 100 current and graduated students. She has also developed and taught courses in the domain of Human Factors and Human Performance, which received high praise from students and brought cutting-edge topics and research into the classroom.

In addition, Major Rusnock leads AFIT's science, technology, engineering, and math (STEM) outreach efforts. Recently she led AFIT's National Engineers Week Committee which fostered collaboration across the Wright-Patterson technical community and helped to promote interest in STEM fields to over 800 students in the Dayton region.



Major Rusnock is also an alumna of AFIT earning her master's degree in Research and Development Management from the Department of Systems and Engineering Management in 2008. As an assistant professor at AFIT, Major Rusnock's research interests include human performance modeling, mental workload, situational awareness, and trust, with a focus on human-machine interaction. She is a member of the Institute of Industrial Engineers and the Human Factors and Ergonomics Society. She enjoys teaching because it allows her to continually share her knowledge and expertise with her peers. "The students are amazing. They are attentive, hard-working, and the best of the best. I truly believe I have one of the best jobs in the Air Force."

FACULTY HIGHLIGHTS

Dr. Paul Hartman PhD, Logistics 2013

Ms. Katie Scott

Dr. Paul Hartman is the Director of the Center for Operational Analysis (COA). The COA is a premier research facility within the Air Force Institute of Technology (AFIT) Graduate School of Engineering and Management, focused on providing world-class logistics, operations, and supply chain management research to solve real-world challenges in near real-world time facing the Air Force and other organizations within the DoD.

"COA is here to serve the interests of USAF and DoD senior leadership. We honor the education, research and consultation mission of AFIT. We think that all of the work that we do in the consultation mode should be used to inform the research and education process of AFIT. When our faculty members serve on our consultation projects, they will be able to take the information and understanding from solving that problem and turn it into real research that is value added to the discussion in their classroom. We aren't just reciting textbooks to our students; we are showing them how the information applies to our AF and DoD."

Current research in the COA includes building a decision support analytic tool for the USAF Blue Horizon Fellows, a group of 15 Air War College students hand-picked to address a specific question on behalf of the Chief of Staff. "The decision support model that we built for them - the Logistics Decision Support Tool - allows leaders to look at the logistics impact of moving forces from one location to another and make an informed impact analysis decision based on the data." Under the leadership of Major Heidi Tucholski, Assistant Professor of Operations Research, the COA has extended the value of this tool into PACAF theater to support their Adaptive Basing concept.

Dr. Hartman and his team are also involved in a several projects supporting USAF interest in the F-35 Joint Strike Fighter program. From advanced modeling and simulation, to business case analysis, "we are excited about what we are doing! We have a fantastic ability to do really good things for the USAF. When I was at AFIT in 1996, I wrote my master's thesis on International Armaments Cooperation in the Post-Cold War Era. International armaments cooperation for the AF at that time was the Joint Strike Fighter program. Twenty years later and here I am today working with the Chief of Staff's F-35 Integration Office to figure out ways to improve the USAF's ability to get that program fielded and to bring that next generation warfighting capability into the USAF mission set."

Dr. Hartman has nearly 30 years of demonstrated expertise serving in a wide variety of program management, supply chain management, maintenance management and logistics policy positions. He earned a M.S. degree in Logistics Management from AFIT in 1997 and a M.A. in International Affairs from the University of Dayton in 1998.

In 2013, Dr. Hartman was the first student to earn a PhD in Logistics from AFIT. The program was designed to combine an analytical core with a flexible program to accommodate defense-focused supply chain management, acquisition, inventory theory, transportation, and operations management thrust areas.

Dr. Hartman's dissertation research, The Outsourcing-to-Insourcing Relocation Shift: A Response of U.S. Manufacturers to the Outsourcing Paradigm, was sponsored by the Deputy Assistant Secretary of the Air Force for Logistics and Product Support. His research examined 24 manufacturing organizations and included 14 specific cases studies where an organization had outsourced manufacturing functions to achieve strategic objectives only to discover that their long-term intended objectives were not achieved. This resulted in executive-level decisions, based on limited decision-quality data, to insource the manufacturing workload back inside their organizations then quickly discovering that they have underestimated the level of resources and skills required to perform the insourced workload. The case studies demonstrated that there was an absence of formal decision making processes supporting the executive-level decision and that the insourcing decision did not result in organization-specific goal achievement.

Dr. Hartman's research findings are now used to inform USAF Senior Leader decisions concerning insourcing of 5th and 6th generation weapon systems into the USAF depot enterprise to meet Congressionally mandated requirements and help the USAF Senior Leaders avoid the many pitfalls of transitioning workload into its organic operations.

AFIT Master's Student - 2d Lt Rachel Oliver

Ms. Katie Scott

Second Lieutenant Rachel Oliver is an AFIT student working towards her master's degree in Astronautical Engineering focusing on satellite design. "The astronautical program here is top notch. I am really happy I got into the program. It's my dream – it's exactly what I want to do."

Born in Winnipeg, Canada, Oliver is a naturalized U.S. citizen. When thinking about where to go to college, she was interested in the military academies "…because it was a way to give back to the country that I could now call home officially," she said. Oliver received an appointment to West Point where she earned an undergraduate degree in mechanical engineering. But her interest in space convinced her to cross-commission into the AF. "I really wanted to be involved in some sort of space-related engineering topic. I have always loved space."

Oliver had originally planned to go to a civilian university for her master's degree following West Point. To help pay for the program, she applied for, and won, a grant from the National Science Foundation (NSF) with a proposal for a new design for an adaptive optic that might fit inside a CubeSAT. "The grant itself allows me to do some networking. They have professional development seminars online and opportunities to reach out to other scientific communities which has been very helpful. But as a military member, I won't use the stipend while at AFIT. I am hoping to get a military deferral for a couple years and use the grant towards a PhD."

When asked about her time at AFIT, Oliver's excitement is expressed with a huge smile. "The classes are great. The satellite design sequence, while it takes a lot of time, is completely rewarding. At the end you have an engineering unit and get to put it on the vibration table to see if it comes apart…I was like 'Wow, I actually created a real product and it's only been a few months!' It was fun and I feel like that is something I would have only been able to do at AFIT."

For her theses, Oliver is applying her computer modeling background to work with software designed to predict the intensity of light reflected off satellites. This fits well with her background in computer modeling. "I am giving a geometric and model based perspective of it and showing what sort of errors can result from the model being a little off or the object being a different shape. The idea is to look at an object in orbit and predict the light that bounces off of it, collected with a ground based telescope, can we predict what the curves will look like. That information will tell us what orientation the satellite is in, or what shape it is, and possibly, what its purpose might be."

A lot of the models that have been used to test known satellites are very intricate and take a long time to make, therefore are very costly. Oliver will make a series of different models of varying complexity and nodes to see which model matches up the best. "I am basically looking for a sweet spot in terms of the detail that is required for an accurate prediction so that future models for unknown satellites can be created quickly and inexpensively."

Oliver has always been interested in science and math, which runs in her family. Her sister, who also earned an NSF grant, is working towards a PhD in oceanography; her father has a master's degree in applied mathematics; and her mother has a doctorate in chemistry and works at Oak Ridge National Laboratory in Tennessee. "I have always had her as a mentor. She is an inspiration to me – a woman and a scientist – I want to be like her."

Following graduation, Oliver hopes to work in AFRL's Space Vehicles Directorate. Reflecting on her journey so far, Oliver says, "For both my undergraduate and then my master's degree, I went to a school that I wasn't expecting. But I always keep the goal in mind of what I really want to be doing. Even though my path hasn't gone exactly where I wanted it, I keep redirecting myself, resetting that vector, and it seems to be working. I am really happy about where I am now."

ALUMNI HIGHLIGHTS

Colonel Christopher Lemanski, M.S. Electrical Engineering 2006

Ms. Katie Scott

Colonel Christopher D. Lemanski serves as Commander, Defense Contract Management Agency (DCMA) Twin Cities, located in Bloomington, Minnesota. He is a career acquisition officer with Air Force assignments spanning weather radar, research, operational test, space acquisition, unmanned aircraft systems, aircrew flight equipment, and life support systems.

Col. Lemanski earned a bachelor's degree in electrical engineering from Parks College of St. Louis University in 1993 and a master's degree in electrical engineering from AFIT in 2006. "I had a great opportunity to attend AFIT and earn an advanced academic degree with follow-on to the National Reconnaissance Office, which was a great experience. AFIT did a phenomenal job of pushing me to expand my educational capacity." Col. Lemanski was a Major when he attended AFIT. His seniority afforded him a leadership opportunity, which he embraced to serve as a class lead. He said this responsibility helped develop his leadership skills and expanded his experience beyond being a student.

In addition to refining his leadership toolset, Col. Lemanski believes his public speaking ability benefited greatly from his AFIT time. "Being able to methodically defend your research as part of the coursework went a long way in preparing me to serve as a team lead and commander. The skills I learned at AFIT such as researching, assimilating large volumes of information, analyzing data, documenting results, and then presenting and defending my conclusions have been foundational for me."

Following his assignment at the NRO where he served as the Chief Space Vehicle System Engineer and Payload Performance Branch Chief, Col. Lemanski was assigned as Program Manager for the MQ-1 Predator System, which is an armed, multi-mission, medium-altitude, long-endurance remotely piloted aircraft that is employed primarily as an intelligence-collection asset and secondarily against dynamic execution targets. Later, he was selected as a Materiel Leader (Acquisition Squadron Commander) for Agile Combat Support in AFLCMC. In 2014, he was interviewed and selected for his first staff assignment as the Chief in AFMC's Commander's Action Group.

"Early in my career, I had the great fortune of being able to apply my engineering degree to engineering problems. But as members of the military workforce advance, there is an expectation that you will grow beyond your immediate technical expertise and apply those foundational skills more broadly and at higher levels of responsibility. An engineer may advance to working systems engineering challenges then to managing technical teams in order to develop a full program perspective. What you learn as you progress through this cycle is how to motivate people with different backgrounds, disciplines and personalities, to focus their talents to realize a specific vision or mission objective."

In 2015, Col. Lemanski was one of two Air Force Fellows assigned to Argonne National Laboratory located in Chicago. Col. Lemanski worked with the Global Security Sciences (GSS) Division, which focuses on helping decision makers protect, mitigate, respond, and recover from a wide spectrum of national and global security threats.

In the end, it's all about accepting the opportunities as they are presented, said Col. Lemanski. "It may be a lot of work, it may push you outside of your comfort zone, but you have to take on those challenges, otherwise you will never know how far you can go."

When asked what advice he would give a new AFIT student, Col. Lemanski said, "…hit the ground running and dig in deep – ask a lot of questions and seek out military and academic mentors. The one thing that is unique about AFIT is the mix of military and civilian instructors. They bring a broader perspective to the learning experience. Take advantage of that. It paid off for me, and I am sure it can benefit you."

ALUMNI HIGHLIGHTS

Dr. Charles Matson PhD, Mathematics 1986

Ms. Katie Scott

Dr. Charles Matson, a member of the Scientific and Professional Cadre of Senior Executives, is Chief Scientist of the Air Force Office of Scientific Research (AFOSR) in Arlington, VA. AFOSR is the basic research manager for the AF; charged to discover, shape and champion basic research that has the potential to profoundly impact the future of the AF.

"My role is to position us well to find the science that will accomplish our mission. Because we cover the entire basic research program for the AF, it encompasses everything from biological systems, chemistry, aircraft systems, and space craft propulsion" said Dr. Matson. Currently, AFOSR is emphasizing four major technical areas: directed energy, human-machine teaming, quantum systems, and hypersonics. "My AFIT education really helped me get the breadth of technical background to be able to carry out the duties effectively."

It is clear when talking to Dr. Matson that he is enthusiastic and driven by the opportunities to impact the AF's research foundation that his position provides. When asked to describe what excites him about his job, Dr. Matson says it is "…having the chance to do the best I can through my organization to set up young scientists to do the basic research that provides the foundation for applied and developmental research which then leads to tangible AF capabilities."

One of the most important skills Dr. Matson has learned over his career is "…the ability to communicate to senior leaders who don't have the technical knowledge base that we do. It is critical to learn how to articulate technical information in a way that continues to build advocacy."

AFOSR invests in long-term, broad-based research with results years, or even decades, in the future. Convincing DOD leaders to make a strong investment in these types of projects could be a hard sell in times of constrained budgets. However, with a budget of $500 million, Dr. Matson states "…the DOD, congress, and the Office of Science and Technology Policy all recognize the importance of basic research. AFOSR is a very active organization seeking the best science. We invest in the tech discovery mission even though we may not know up front how that might apply to the AF because many, if not most, of the huge breakthroughs did not start by knowing the mission that they were going to meet. That is why we choose to invest in emerging technologies."

In between his AF military career and his AF civilian career, Dr. Matson was an assistant professor in the electrical engineering department of Seattle Pacific University. But the world felt small at a traditional university and he missed the opportunities to have a real impact on the AF mission. In 1993, he returned to the AF and worked as a research scientist within AFRL. Dr. Matson has conducted research in a variety of areas including space surveillance technologies, laser propagation, biomedical imaging, high-performance computing, and image and signal processing theory.

"An AFIT education is absolutely relevant today and, in my opinion, will always have a role in preparing researchers to make a difference in the AF" commented Dr. Matson. "Scientists in the government have such a unique opportunity to have an inordinately big impact on the direction of what the future AF is going to look like. People shouldn't underestimate that."

Colonel Marc Sands, M.S. Nuclear Engineering 1999

Ms. Katie Scott

Colonel Marc Sands is the Chief of the Nuclear Operations Division for the U.S. Air Forces in Europe (USAFE) located at Ramstein Air Base, Germany. He leads 61 personnel and is the command lead for all nuclear operations, plans, security, maintenance, and command and control. "The mission set is so unique. In this position, probably more than any other I have had, I really feel the relevance of it and there is an urgency to make sure we get it right. One of the challenges of this position is working with our foreign partners who support the nuclear mission set. Sometimes there are cultural differences, language barriers, as well as just issues making sure that this mission area, which is always under scrutiny, is working properly. It's a positive challenge, because I have a lot of good people working with me to make sure the mission doesn't fail" stated Col Sands.

Sands earned a bachelor's degree in space physics from the USAF Academy and then served as an analyst and researcher at the National Air Intelligence Center (NAIC). He then joined AFIT and earned a master's degree in nuclear engineering in 1999.

When talking with Col Sands about his education and career it is clear that he is a very driven and focused person and most of the demands placed on him are self-imposed. While some people would shy away from putting themselves in difficult positions, Col Sands seems to thrive; but he is very honest and direct about the amount of hard work, long days and personal sacrifices that must be made to make it through.

"I learned very early on that academics do not come naturally to me. I was not the best student and to compete with the people around me I had to work harder. When I graduated from AFIT I honestly felt relieved that I had made it. At AFIT I learned critical thinking skills and an immense amount of technical information. It wasn't a comfortable experience, but I am glad I did it." Speaking directly about AFIT, Col Sands' says, "I definitely see a benefit and need to having an AF focused education where students get the technical education while focusing on an AF issue. We are in a more technical environment and an AFIT education helps posture graduates to lead in these changing situations."

Col Sands has not followed the traditional career path of a 61DN scientist. "I have been lucky enough to have many very cool, very interesting jobs that most scientists don't normally have access to." One of his favorites is the assignment to the Central Intelligence Agency's office of the Assistant Director of Central Intelligence for Collection where he was the Measurement and Signature Intelligence (MASINT) program technical collection analyst. "This was the most unique, exciting and rewarding position from a career and knowledge perspective, but it was also the most stressful and time consuming of the positions that I have held."

To be successful in assignments, Col Sands says that the key is asking a lot of questions, listening to the answer, understanding how things work and putting those pieces together. "Often times, folks will go into a job and not understand where that job fits into the mission set of the branch, division, or organization. You can only understand that by talking to folks and really listening to the answers – focus on what might be keeping that person or group from succeeding either better, or faster, and use your best judgement to make the difficult decisions. You can't be passive."

In 2015 Col Sands was selected as an Air Force National Laboratory Technical Fellow at the Oak Ridge National Laboratory in Knoxville, Tennessee where he conducted base and applied research. "Most of my career has been in support of intelligence collection and analysis. Going to Oak Ridge was going back to an area that I had not done a lot of work in since my time at AFIT. That is where the skills that I learned early in my career to ask a lot of questions and engage people in conversations about what they are working on and how it fits together helped me. I was able to go into a lab environment and learn from the researchers to connect what Oak Ridge is trying to do with AF and DoD costumers to match capabilities and needs."

His advice for others is: "Make sure that at the end of the day you are happy with the decisions you have made. Find what motives you, work hard, and definitely don't quit. Be an active participant in making decisions on where the balance is for you and don't let systems or people push you into situations where you will feel regret in the end."

Selected Large Awards for Fiscal Year 2016

"B-2 Defense Management System (DMS) RDT&E Effort for Evolving Air Force Operational Requirements" $1,500,000 - Air Force Life Cycle Management Center
Principal Investigator: Dr. Jeffery Weir

"System Level Functional and Performance Requirements for the Special Mission Suite (SMS) System on the AC/MC-130J" $850K - United States Special Operations Command
Principal Investigator: Dr. Paul Hartman

"F-35 T&E Support: Verification and Validation for the Virtual Simulation Environment"
$734K - F-35 Joint Program Office
Principal Investigator: Dr. Darryl Ahner

"GNSS Testbed Development"
$728K - Air Force Research Lab Sensors Directorate
Principal Investigator: Dr. Sanjeev Gunawardena

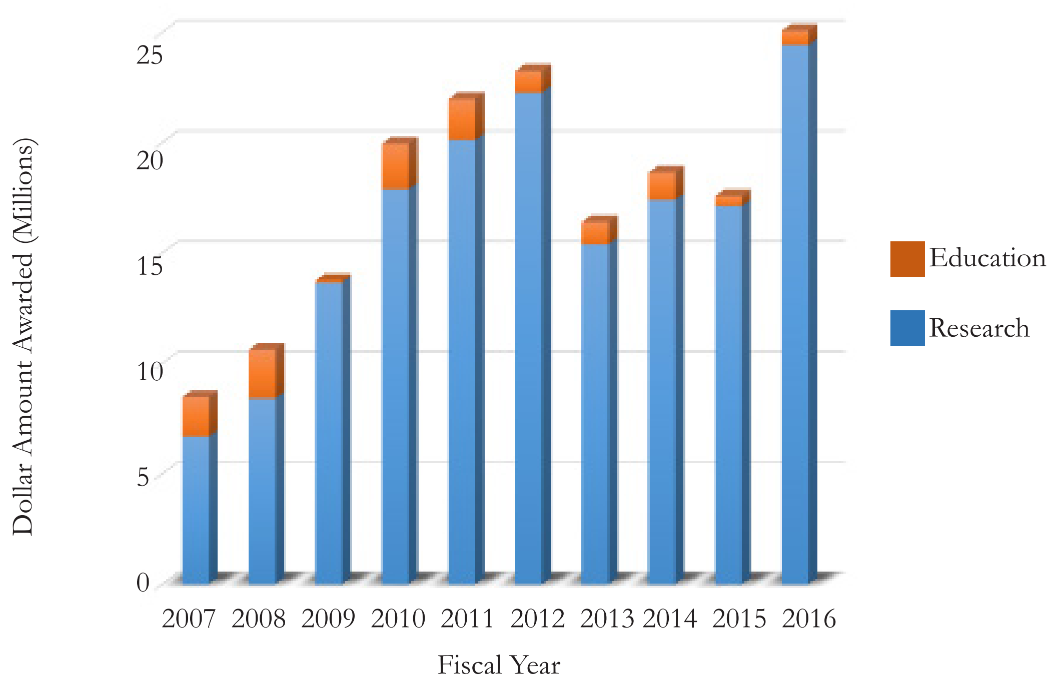
"Research, Development, Test and Evaluation (RDT&E) for the Presidential Aircraft Recapitalization (PAR) Program" $620K - Air Force Life Cycle Management Center
Principal Investigator: Dr. Paul Hartman

"Scientific Test and Analysis Techniques for Automatic Test and Analysis" $500K - Naval Sea Systems Command
Principal Investigator: Dr. Darryl Ahner

"Value-Driven Tradespace Exploration and Analysis for Resilient Systems"
$410K - USA Engineer Research and Development Center
Principal Investigator: Dr. Jeffery Weir

"CY2016 HELJTO M&S TAWG Product Development"
$400K - High Energy Laser Joint Technology Office
Principal Investigator: Dr. Steve Fiorino

New Award History Fiscal Year 2006 - Fiscal Year 2016

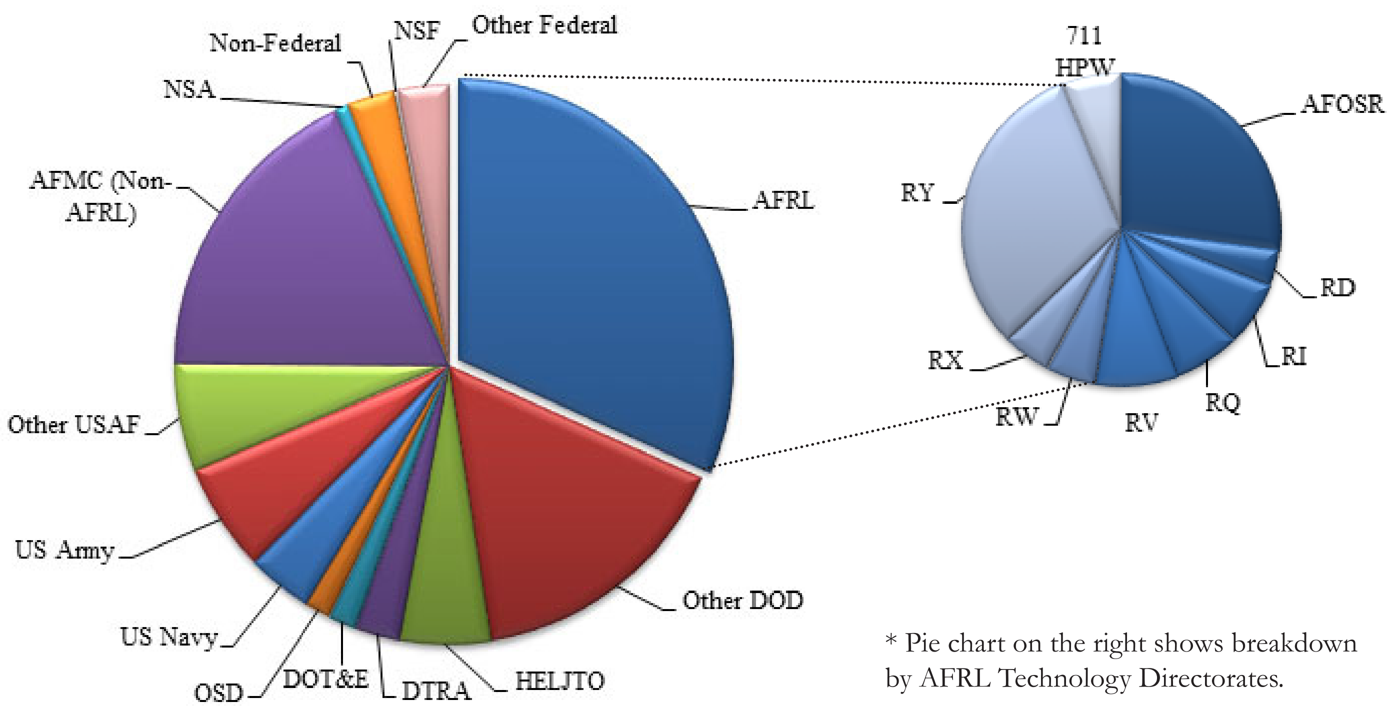


Sponsors of Fiscal Year 2016 Projects

	Newly Awarded Research Projects		*Newly Awarded Education Projects*		*Total FY16 Newly Awarded Projects*		*Total FY16 Research Expenditures*
Departments	#	*$k*	#	*$k*	#	*$k*	*$k*
Mathematics & Statistics (ENC)	7	544	-	-	7	544	458
Electrical & Computer Eng (ENG)	62	6,225	3	196	65	6,421	5,836
Engineering Physics (ENP)	57	5,576	2	19	59	5,595	5,177
Research & Sponsored Programs (ENR)	1	351	-	-	1	351	-
Operational Sciences (ENS)	27	8,328	3	176	30	8,504	5,518
Systems Eng & Management (ENV)	15	955	2	195	17	1,150	719
Aeronautics & Astronautics (ENY)	48	2,456	3	59	51	2,515	1,985
TOTAL	**217**	**24,436**	**13**	**645**	**230**	**25,080**	**19,693**
Center	#	*$k*	#	*$k*	#	*$k*	*$k*
Autonomy and Navigation Technology (ANT)	29	3,716	1	175	30	3,891	3,447
Center for Cyberspace Research (CCR)	20	1,147	3	196	23	1,343	959
Center for Directed Energy	25	3,276	1	9	26	3,285	2,822
Center for Operational Analysis (COA)*	23	7,085	2	150	25	7,235	4,555
Center for Space Research and Assurance (CSRA)	18	1,339	-	-	18	1,339	1,266
Center for Tech Intel Studies & Research (CTISR)	15	1,136	1	10	16	1,146	1,294
TOTAL	**130**	**17,669**	**8**	**540**	**138**	**18,239**	**14,343**

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.

New Fiscal Year 2016 Awards to Academic Departments and Research Centers



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

ENROLLMENT INFORMATION

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 master's or doctoral degree. Tuition will be waived for all Air Force military and Air Force civilians, who are not sponsored by the Air Force to enroll at AFIT on a space-available basis.

Our automated application system 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 Engineering Accreditation Commission (EAC) and the Applied Science Accreditation Commission (ASAC) of ABET accredits our eligible engineering and applied science 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 6:1. In the academic year 2015-2016, 337 master's and doctoral degrees were awarded to 253 AF officers, 3 AF enlisted, 28 sister services, 41 civilians, and 12 international military officers. Our campus consists of eight buildings, 23 class laboratories, 67 research/laboratory areas, and the D'Azzo Research Library.

For more information, visit www.afit.edu/admissions.

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 visit www.socheintern.org.

RESEARCH & CONSULTING

AFIT Research Centers

Autonomy and Navigation Technology Center	www.afit.edu/ANT/	Dr. John Raquet
Center for Cyberspace Research	www.afit.edu/CCR/	Lt Col Mark Reith
Center for Directed Energy	www.afit.edu/CDE/	Dr. Steven Fiorino
Center for Operational Analysis	www.afit.edu/COA/	Dr. Paul Hartman
Center for Space Research and Assurance	www.afit.edu/CSRA/	Col Dane Fuller
Center for Technical Intelligence Studies & Research	www.afit.edu/CTISR/	Dr. Kevin Gross
OSD Scientific Test and Analysis Techniques Center of Excellence	www.afit.edu/STAT/	Dr. Darryl Ahner

Sponsoring Thesis Topics

AFIT encourages input from your agency that aligns our research and student education to relevant areas to ensure the technological superiority and management expertise of the U.S. Air Force and the DOD. 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.

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